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BUREAU OF PLANT INDUSTRY,
B. T. GALLOWAY, *Chief of Bureau.*

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B. T. GALLOWAY, *Chief of Bureau.*

SEASONAL NITRIFICATION AS INFLUENCED BY CROPS AND TILLAGE.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 23, 1909.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 173 of the series of this Bureau the accompanying manuscript, entitled "Seasonal Nitrification as Influenced by Crops and Tillage," by Mr. Charles A. Jensen, Agriculturist, of this Bureau.

The Office of Dry-Land Agriculture, of this Bureau, is carrying out extensive investigations in crop rotation and cultivation methods at thirteen stations located at widely different points in the Great Plains area. The purpose of these investigations is to ascertain the best methods of agriculture in these semiarid regions. To do this intelligently it is necessary not only to study the immediate effect of these methods on crop yields, but also to study the resultant changes occurring in the physiological properties of the plant nutritive solution, which is recognized as one of the fundamental factors in crop yields. It is therefore necessary to supplement the field work with laboratory investigations having for their aim the solution of the problems presented by the crop returns from the rotation systems mentioned.

The accompanying manuscript shows the seasonal changes in the water-soluble nitrates in summer-fallowed land, wheat land, and corn land and the rates and extent of the seasonal removal of the nitrates by these crops. The investigations were made by Mr. Jensen while he was superintendent of the Bellefourche substation of the Office of Dry-Land Agriculture. The work was conducted in cooperation with the Physical Laboratory of this Bureau, which has general supervision over the physical measurements carried out at the dry-land stations of the Bureau.

The results described in the paper are, I believe, sufficiently significant to demonstrate the importance of a more extended development of this line of investigation at the stations.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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SEASONAL NITRIFICATION AS INFLUENCED BY CROPS AND TILLAGE.

INTRODUCTION.

The attempt to bring the vast areas of prairie lands of the Great Plains under a profitable system of agriculture has been undertaken with renewed vigor during the last few years, both by the older settlers and by many new ones entering the Plains. These new settlers come mainly from the Middle West, where the climatic and soil conditions are very different from those in the newer areas where they settle. On the Great Plains the rainfall is likely to be too little rather than too much for good crop returns and, moreover, it does not always come at the time most convenient for the farmer; besides, the wind movement, especially in the spring, when the crops are being planted and when the surface of the soil is usually exposed in a rough condition, saps the soil of its moisture very rapidly.

Under such conditions it becomes necessary to control the quantity and the movement of the soil moisture, and as this moisture constitutes the plant nutritive solution it is obvious that not alone the absolute amounts of soil moisture present but the nutritive character of this solution become of importance, so that any cultural system inaugurated for the purposes of moisture conservation should be such that the quality as well as the quantity of the nutritive solution can be controlled.

It has often been observed that of two contiguous plats on the same type of soil one may yield considerably higher than the other, although the amount of soil moisture may be the same in both. In such cases it is often found that the properties of the nutritive solutions from the two plats are markedly different in their behavior toward plant growth, and often the history of the plats will show that the cultural methods have been different and that these may explain the differences found in the character of the soil moisture constituting the plant nutritive solution. The mere storing up, then, of soil moisture is not always sufficient for the purposes of good crop returns.

During the last few years a number of substations have been established by the Bureau of Plant Industry throughout the Great Plains area for the purpose of finding out, if possible, the best methods of handling the prairie lands there so that profitable crop returns might be realized. At all of these stations a large number of rotations have been established, and other plats have been set aside for experiments with various methods of cultivation without regard to crop rotations.

In the spring of 1907 the writer was put in charge of the substation at Bellefourche, S. Dak., where experiments in dry-land agriculture were inaugurated. The station site was on virgin prairie lands, so nothing was done that year beyond breaking up and preparing land for use in 1908. In the spring of that year an elaborate series of rotation systems was established, and a large number of other plats were set aside for use in the studies of soil-moisture conservation by different methods of cultivation, the success of the methods being measured finally by the crop yields, though moisture determinations were made during the entire season.

The work to be described was done on some of the plats used for the purpose of trying out different cultural methods, it being thought that different crops and different tillage methods would influence the nutritive properties of the soil solution. Owing to the press of field duties and to the inconvenient location of the station as regards supplies, it was found necessary to limit the laboratory work to a study of the natural activity of nitrification in the soil as measured by determinations of nitrates, nitrites, and ammonia in three plats receiving different treatments and bearing different crops.

The literature on nitrifying organisms and on nitrification is very voluminous, and while the author does not by any means claim to have read it all, it is believed that most references which have any direct bearing on the present subject matter have been cited. In no case was there found reported work on nitrification in the field as influenced by crops and tillage that had been carried on continuously throughout the crop season. The few references found which might have a bearing were generally reports on work carried on in humid regions or in the laboratory, the conclusions of which could hardly be extended to the semiarid regions. Much of the literature, however, was helpful in formulating suggestions explaining the phenomena found.

DESCRIPTION OF THE SOIL IN WHICH THE EXPERIMENTS WERE CONDUCTED.

The soil of the station and of the surrounding country is known as "gumbo" and is a heavy, black or gray, clay loam to a depth of 2 to 3 feet, and below this depth heavy clay usually occurs, extending to 6 feet or deeper, overlying the partially disintegrated cretaceous shale which is the geological formation of the whole surrounding country.

FIELD HISTORY OF THE PLATS.

The prairie sod, covered originally with western wheat-grass (*Agropyron occidentale*), buffalo grass (*Bulbilis dactyloides*), and gramma (*Bouteloua oligostachya*), with minor quantities of sedges (*Carex filifolia* and *C. stenophylla*) and other grasses, together with a few vetches, was broken in the spring of 1907 to a depth of about 3 to 4 inches, backset (replowed) in the fall of 1907 to a depth of about 5 inches, and left open until the spring of 1908, when it was disked and harrowed until a good seed bed was secured. Such was the treatment of the spring-wheat plat and the corn plat used in the work. A plat reserved for summer-fallow used in this work was spring-plowed to a depth of about 8 inches, smoothed with a disk, and harrowed. This plat was cultivated during the summer to keep weeds down and to conserve the moisture.

The determinations on the corn plat were not begun as early as on the wheat and fallow plats. As this plat was not planted as early as the wheat plat, it was taken for granted that the soil conditions would be the same as those of the fallow plat until the time of planting the corn.

METHODS OF MAKING DETERMINATIONS.

The chemical methods used were those described in Bulletin No. 31 of the Bureau of Soils. The soil samples were collected in duplicate from 6-inch layers to a depth of 2 feet—that is, in 0 to 6, 6 to 12, 12 to 18, and 18 to 24 inch depths—and the two cores from each soil layer made into a composite sample. The samples as bored up with the auger were transferred to air-tight tin cans, taken immediately to the laboratory, weighed, dried in an oven at a temperature of about 100° C., and again weighed. In preparing the solution it was found necessary to adopt this drying method in order to insure thorough mixing of the soil and the water, as it was practically impossible to break down the moist gumbo pieces directly. The ratio of soil to water was 1 to 5 (100 grams of soil to 500 c. c. of water). After drying, the soil particles readily broke down and after thorough stirring in the water would settle out quite clear in about 20 to 30 minutes. The supernatant liquid was then poured into Chamberland filters and filtered. Such a procedure of drying the soil could, of course, not be employed were determinations to be made of such soil elements as are derived directly from the soil minerals, as potassium, phosphoric acid, etc., but owing to the origin and nature of the nitrates and nitrites in the soil the solubility is not increased; neither is it likely that decomposition of a disturbing nature would take place. Experiments were made to compare the two methods of obtaining the soil solutions from soil that was first dried and from undried samples direct from the field. The results agreed within the limits of experimental error, and as better mixing was possible by using the dried samples this procedure was an advantage.

The determination of nitrates under ideal conditions does not present any serious difficulty if the procedure is carefully followed out and precaution against errors observed. As is well known, however, difficulties are likely to be encountered when nitrates are to be determined in soil extracts, especially if the extract is highly colored with soluble organic matter or if it contains considerable soluble inorganic salts, especially chlorids. There are thus three main sources of error in nitrate determination in a soil extract: Foreign organic color, which is superimposed on the yellow color developed on nitration of the phenoldisulphonic acid, which renders the colorimetric reading more difficult; the soluble organic matter may be acted upon by the nitrates, or possibly by the acid, thus introducing a chemical error; the presence of considerable amounts of alkali salts, of which chlorids seem to be the most serious ones.

The soil extract obtained in the work here reported did not contain enough chlorids to cause error, as the amounts were too small to measure accurately by means of titration; only traces were ever observed, and frequently none at all.

The errors which might be introduced because of the presence of soluble organic matter are believed to be too small to seriously consider, as the only soil samples which gave appreciable organic colors were those from the fallow plat, and no serious difficulty was encountered in making the colorimetric readings of these extracts, the organic color being of quite a different shade from the yellow color due to nitration. The error which may have been introduced through the chemical disturbance of the organic matter was neglected, it being considered too small to be of serious consequence; as stated above, the organic color was not strong. All points considered, it was decided that under the circumstances and conditions less error would be involved in using the solutions directly as obtained than by trying to free them of organic matter by oxidation or reduction.

It should be kept in mind that the chief value of the results obtained lies in their relativity more than in the absolute amounts found. This weekly relation of the amounts of nitrates in the various soil layers in the various plats could not be seriously disturbed by any slight error which might possibly have been introduced because of the presence of soluble organic matter in the soil extracts.

It has been quite well made out that no appreciable error was introduced in quickly drying the soil samples in the oven at 100° C.

This was established at the time and has been also found in the bacteriological laboratory of this Bureau to be a safe procedure for purposes of comparison.

A comparison of results obtained by the various methods of extraction is given in Table I.

TABLE I.—*Nitrites, nitrates, and ammonia found in dry soil treated in various ways.*

Soil treatment.	Parts per million in dry soil.		
	Nitrites (NO_2).	Ammonia (NH_3).	Nitrates (NO_3).
Fresh untreated soil, using undistilled water	0.55	1.5	26.7
Fresh untreated soil, using distilled water	.55	.8	22.2
Fresh untreated soil plus chloroform, using undistilled water	.55	2.5	22.2
Fresh untreated soil plus chloroform, using distilled water	.55	2.0	25.0
Soil dried in oven at 100° C	.55	3.33	36.4

The oven-dried sample in this case gave a higher proportion of ammonia and nitrates than the other samples. It is possible, though, that nitrification went on to some extent before the sample was properly dried, as the gasoline drying oven was troublesome, this being its first use. The soil sample was in the oven most of the day before the trouble with the burner was located, and it was warmed most of the day without quickly drying.

The following set was run through the next day, a soil being used that had been carefully prepared for a winter-wheat seed bed the previous year but which had not been planted:

TABLE II.—*Nitrites, nitrates, and ammonia found in dry soil from a seed bed treated in various ways.*

Soil treatment.	Parts per million in dry soil.		
	Nitrites (NO_2).	Ammonia (NH_3).	Nitrates (NO_3).
Fresh untreated soil immediately extracted	0.28	....	133.3
Fresh soil plus chloroform and immediately extracted	.28	....	133.3
Fresh soil after three hours' treatment with chloroform and dried quickly at 103° C	.20	....	133.3
Fresh soil dried immediately in oven without being treated with chloroform	.33	....	133.3

The ammonia was not read, as the solution contained foreign coloring matter. These and the previous results give an idea of the limits of experimental error. The standard solutions used for comparison in the colorimeter were made up fresh on the day they were used, and all readings were made within a few hours. The nitrite reagents were kept separate and small portions mixed as needed for use.

The systematic determinations were begun April 27, and from then until July 31, about ten days after harvest, the determinations were made once a week.

DISCUSSION OF RESULTS OF DETERMINATIONS.

NITRATES IN THE FALLOW PLAT.

Figure 1 shows the parts per million of nitrates calculated for the oven-dried soil in each 6-inch layer in the fallow plat from April 27 to July 31 and the precipitation for the same period. About 1 inch of rain had fallen from April 1 to April 27. The weekly periods are laid off on the abscissa, and the parts per million of nitrates on the ordinate. The precipitation scale is on the right-hand side of the figure.

The first two sets of determinations show decreasing amounts of nitrates from the surface 6-inch layer downward, the second foot containing very small amounts. There were no marked changes until May 9, when the surface 6 inches of soil showed a considerable increase in nitrates, and it is also seen that at this time this soil layer contained a maximum amount of water-soluble nitrates. The nitrates in the second layer, 6 to 12 inches, had more than doubled since the week before, but there were no considerable changes in the lowest two layers. By the next week, May 16, the surface 6 inches of soil had decreased about forty parts per million, and there was also a decrease in the 6 to 12 inch layer. By the next week, on May 22, a marked increase in the amount of nitrates is evident in the 12-inch layer, it having increased about seventy parts per million during six days, and the surface 6-inch layer had decreased about ten parts per million. At this date the 12-inch layer contained the maximum quantity of

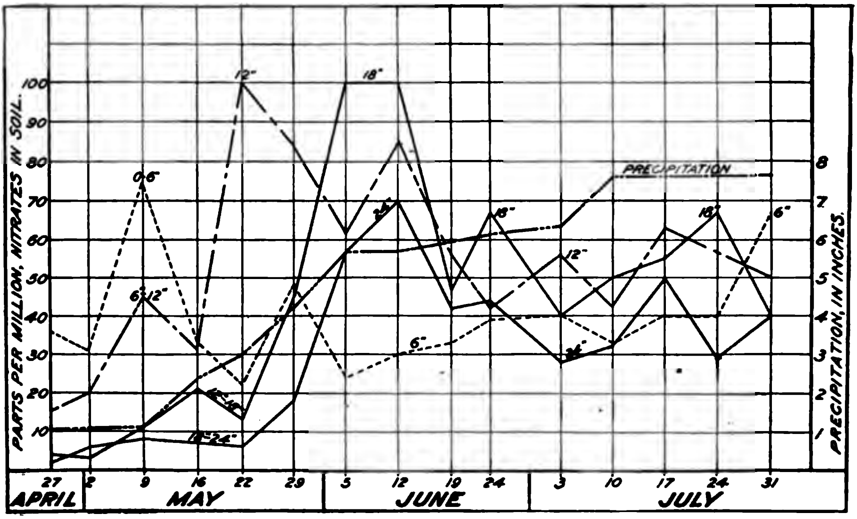

FIG. 1.—Diagram showing the parts per million of water-soluble nitrates in dry soil in the fallow plat in each 6-inch soil layer to a depth of 2 feet; also precipitation curve.

nitrates. Up to this time there were no great changes in the nitrates in the 18 and 24 inch layers, but from May 22 to June 5 these layers accumulated considerable amounts, and on the latter date the 18-inch layer contained the maximum, which remained constant until the next week, June 12. In the mean time, the 24-inch layer accumulated considerable quantities of nitrates, reaching its maximum on June 12.

It will be noticed in general that from April 27 to June 5 the maximum amount of water-soluble nitrates shifted every two weeks to the next lower layer and that once any layer had accumulated a maximum it decreased and in general never again contained as large amounts as the maximum of the next lower layer, which was reached at a later date.

From June 12 to June 19 there was an interesting change, in that every soil layer which had recently been actively accumulating nitrates suddenly showed a marked decrease in amounts of water-soluble nitrates, and all of the layers on June 19 contained nearly the same amount of nitrates. The upper 6-inch layer did not show any such decrease, the reason for which will be discussed later on. From June 19 till July 31 there were no regular changes, all of the curves zigzagging irregularly.

In view of the marked increases in the amount of nitrates in the 18 to 24 inch layer, it is to be regretted that determinations were not made in the third foot also, but time did not permit the increased work. The 18 to 24 inch layer never contained a maximum amount of nitrates in comparison with the other layers, but the results certainly indicate that nitrification is quite active at a depth below 2 feet in these prairie soils when they are brought under cultivation. Bazarewski[a] found very few nitrifying bacteria, however, at a depth of 50 centimeters and reports that they were "plentiful at a depth of 10 centimeters." It will be noticed from figure 1 that the 18 to 24 inch soil layer accumulated as much water-soluble nitrate as did the 0 to 6 inch layer, so nitrifying organisms are presumably active in this prairie soil to a depth considerably greater than 2 feet. Hunt[b] likewise reports that nitrification took place to but a small extent below a depth of 2 feet, and the figures given by him show that under the conditions discussed nitrification was not very active in even the second foot.

In this connection it may be of interest to mention that the unbroken prairie "gumbo" never becomes moistened deeper than about 8 to 10 inches even after the heaviest rains. Cultivation, however, soon results in the soil becoming moistened deeper than 6 feet within one year after breaking the sod and cultivating the soil. It is fair to assume, therefore, that nitrification in the unbroken land can not take place to any great extent much below a depth of 1 foot.

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[a] Bazarewski, L. von. Nitrification and Denitrification in Soils. Reviewed in Experiment Station Record, vol. 21, no. 1, July, 1909, pp. 20–21.

[b] Hunt, T. F. The Importance of Nitrogen in the Growth of Plants. Bulletin 247, New York (Cornell) Agricultural Experiment Station.

NITRATES IN THE SPRING-WHEAT PLAT.

Figure 2 shows the results obtained from determinations made on the spring-wheat plat. These determinations were not begun until May 9, but a vertical section made in figure 1 on May 9 will show that the order is about the same at this point on both figures.

Figure 2 does not contain the precipitation curve, but in addition to the curves showing the amounts of nitrates in the 6-inch soil layers, it shows the curve representing the weekly increase in the dry weight of the wheat plants. The increase was determined each week by cutting four 3-foot squares, two near each end of the 2 by 8 rod plat, both green and air-dry weights being obtained. Only the dry weights are platted in the figure.

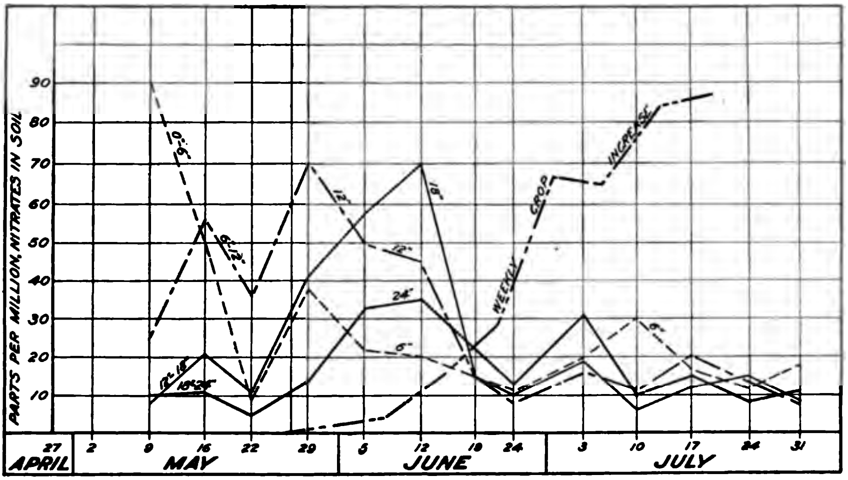

FIG. 2.—Diagram showing the parts per million of water-soluble nitrates in dry soil in the spring-wheat plat in each 6-inch soil layer to a depth of 2 feet; also weekly increase of wheat plants.

A comparison of figure 1 and figure 2 shows the same general fact, namely, that the maximum amount of water-soluble nitrates in any soil layer is shifted every two weeks to the next lower layer. The detailed variations are about the same in the two plats, but there is one general difference—the date of the maximum accumulation of nitrates in the respective soil layers in the two plats is shifted one week forward in the case of the spring-wheat plat—that is, each of the 6, 12, and 18 inch layers, respectively, attained its maximum accumulation of water-soluble nitrates just one week later in the wheat plat than in the fallow plat. It will be remembered that it was stated that the fallow plat was plowed to a depth of about 8 inches in the spring of 1908 and that the wheat plat had not been plowed since being backset in the previous fall to about 5 inches deep. There was thus a difference in the mechanical condition of the two plats; the summer-fallow plat being more open and stirred to a greater depth, there was presumably a more rapid access of air, and in consequence a more rapid rise in temperature. Hunt[a] also found that early plowing promoted nitrification more rapidly than late plowing, and presumably early plowing would promote nitrification more rapidly than no plowing at all.

It was expected that some information would be obtained in regard to the rate at which the growing wheat plants removed the nitrates from the different soil layers, that being one of the main points sought for in the work. As a matter of fact, it will be noticed that the curves of the two figures are so much alike in the general trend that were they not scaled or labeled in any way it would be difficult to say which figure represented the fallow plat and which the wheat plat. The shifting of the dates of the maximum accumulation of nitrates in the individual soil layers one week back in the case of the fallow plat might be explained by the difference in the tillage. By using the fallow plat as a check on the wheat plat, which is really what it is, it will be noticed that aside from this shifting already mentioned the only general differences are the smaller amounts of nitrates found in the wheat plat and that after June 19, when the general decrease in nitrates took place—as in the fallow plat—the nitrates in each soil layer in the wheat plat were more constant in both total amounts and amplitude of variation. Had the results on the fallow plat not been obtained as a check on the results obtained on the wheat plat, it might have been supposed that during the time immediately following June 12, when the wheat plants were making rapid increase in growth, the crop was removing nitrates much more rapidly than they were being formed. Even thus one would hardly expect the nitrates to be removed so spontaneously and almost completely from each 6-inch soil layer. One can not, then, from the amounts of water-soluble nitrates found, determine the soil layers in which the wheat roots were feeding most rapidly or demonstrate any progressive downward ranging of the roots as the season advanced. The apparent "removal" of the nitrates from the soil is due, then, to some other factor than the presence of the crop.

Even after June 19, when the marked decrease in the amounts of water-soluble nitrates occurred, there is no consistent correlation between the weekly increase in the dry weight of the wheat crop and the amounts of nitrates present. On the contrary, from June 24 to July 3 there was a general increase in the amounts of nitrates corresponding to the greatest weekly increase in the growing crop.

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[a] Hunt, T. F., loc. cit.

COMPARISON OF NITRATES IN FALLOW, SPRING-WHEAT, AND CORN PLATS.

Figure 3 shows the amounts of nitrates—averages of the four 6-inch soil layers—found during the season in the wheat plat, the fallow plat, and the corn plat; also the precipitation curve and the weekly crop-increase curve. It is to be regretted that the same amount of data could not have been obtained from the corn plat as from the wheat plat, but time did not permit. Nothing much can be said about this curve beyond the statement that the rapid decrease in nitrates corresponds quite closely to the period of most rapid growth of the corn as recorded in the notes at the time.

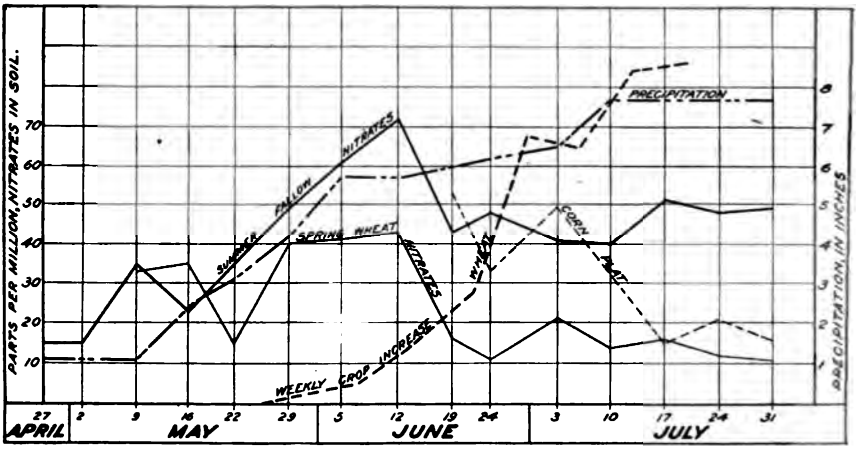

FIG. 3.—Diagram showing the average parts per million of water-soluble nitrates in dry soil to a depth of 2 feet in the summer-fallow, spring-wheat, and corn plats; also weekly increase of wheat plants and precipitation curve.

The corn plat had evidently accumulated quite large amounts of nitrates before the plants were large enough to materially draw upon these salts, for the corn curve shows that on June 19 the accumulation of nitrates in the corn plat had reached about the same point as that in the fallow plat. The direction of the corn-plat curve from June 19 to June 24 also suggests the general drop found in the fallow and wheat plat curves. As the corn was not planted until May 7, the plat was evidently in a state of summer fallow until determinations were begun. During the most active growing period of the corn these plants evidently reduced the amounts of nitrates to as low a content as did the wheat plants in the wheat plat. Apparently the corn plants were as fond of the nitrates as were the wheat plants. The general field observation that a corn crop renders the ground more productive for grain than a previous grain crop is apparently not due to the leaving of greater amounts of nitrates in the soil.

WITHDRAWAL OF NITRATES BY CORN ROOTS.

As already mentioned, the general decrease in the amounts of water-soluble nitrates in both the fallow and the wheat plats masked the effect of any progressive withdrawal of the nitrates by the wheat-plant roots in the successive soil layers. In the case of the corn plat, however, there was the advantage of the fact that the nitrates had already been accumulated, and so the corn offered an opportunity for observing the removal of nitrates from the various soil layers as the season progressed. Figure 4 shows the probable effect of the feeding of the corn roots and indicates that the surface 6-inch layer early lost considerable amounts of nitrates and that very shortly thereafter the 12-inch layer was drawn upon most heavily. From July 3 to July 17 the corn plants made their most rapid growth, and the curves also show that at this period the nitrates were most heavily drawn upon. The 18-inch layer contained most nitrates and lost most. All of the layers to a depth of 2 feet were probably reduced to the limit of the powers of the corn roots to withdraw nitrates from this heavy soil.

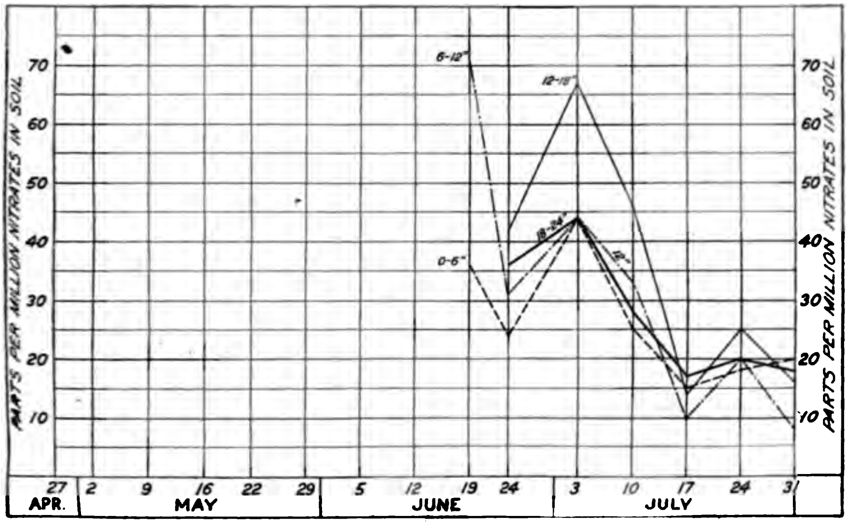

FIG. 4.—Diagram showing the parts per million of water-soluble nitrates in dry soil in each 6-inch soil layer in the corn plat to a depth of 2 feet.

The curves in figure 4 also show variations in the activity of nitrification, especially an increase from June 24 to July 3, but the progressive downward feeding of the corn roots seems clearly shown. The characteristic manner of surface feeding of corn roots would early draw upon the plant food in the surface soil, as indicated in figure 4 by the curves of the 6 and 12 inch layers. The soil samples, however, were taken not between the corn rows, where the lateral roots only were abundant, but as near the corn plant as they could be taken, not more than 3 or 4 inches away. Such sampling would encounter the primary roots of the corn, as well as penetrate the soil area in which the lateral roots were feeding most actively, and it seems probable that the reduction of the amounts of nitrates in the 18 and 24 inch layers was due to the penetration of these primary roots to that depth. This would account for the tardy removal at the lower depth, as the primary roots would be longer in reaching these lower layers. The moisture determinations showed that the moisture was being removed quite rapidly from the 18 and 24 inch soil layers at the same time.

The most striking feature about figure 3 is the general parallelism of the nitrate curve of the wheat plat with the nitrate curve of the fallow plat. The seven-day lagging of the maxima in the wheat plat is not, however, as clearly shown here as in figures 1 and 2, but is evident in the early part of the season. The only other point of difference in the two curves is in the period from May 29 to June 12, during which time the summer-fallow plat steadily accumulated nitrates, while there was a bare increase in these salts in the wheat plat. This is the period during which the fallow plat laid in its increased stock of water-soluble nitrates, and from June 12 on there is a constant difference of about twenty to thirty-five parts per million in favor of fallowing. It is probable that this difference represents in general the continuous amount of soluble nitrates used up by the plants. It is, however, also likely that had more nitrates been formed the plants would have used them and that the curves represent in a general way the minimum amount to which the corn and wheat roots can reduce the nitrates in this heavy soil. Traps [a] found that the nitrogen content of crops was increased with an increased nitrifying activity in the soil.

In figure 3 no close relation is evident between the weekly crop-increase curve and the decrease in the nitrates, using the fallow curve as a check.

RELATION OF NITRIFICATION TO FIELD FACTORS.

The nitrification in the soil depending, as it does, on so many factors—temperature, moisture, aeration, organic matter, kind of crop, cultivation, etc.—it is difficult in the field to run down the specific physical or chemical factors most influential in the promoting of the formation of nitrates in a given soil type. An attempt was made to correlate the variations in and the amounts of the nitrates found during the season with some of the factors known to influence their formation. As some of the most important ones from a chemical or bacteriological standpoint could not be taken up at the time the attempt at correlation had to be confined to a consideration of some of the physical factors. As, however, the soil of the different plats was similar and probably as nearly uniform as it is possible to obtain soil in different plats, and, furthermore, as the past history of the plats was exactly the same up to the time of beginning the work, it is not likely that there were any fundamental chemical or bacteriological differences in the plats at the time of planting. The wheat and corn plats were adjacent and were separated from the fallow plat by only 6 rods, and certainly no differences were apparent. Continuous air-temperature records were kept by means of a thermograph, but no evident relation could be obtained between the variations in amounts of nitrates and in temperature, whether the mean maximum, mean minimum, or general mean temperature was considered.

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[a] Traps, G. S. Bulletin 106, Texas Agricultural Experiment Station, p. 4.

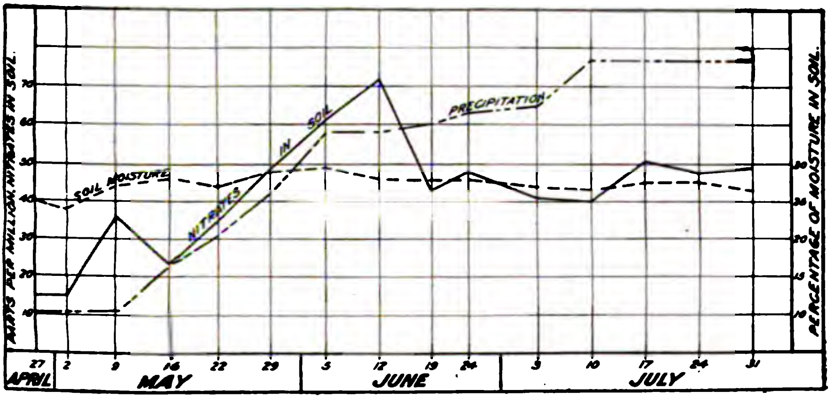

FIG. 5.—Diagram showing the average parts per million of water-soluble nitrates in dry soil in the fallow plat to a depth of 2 feet; also soil-moisture curve and precipitation curve.

Figure 5 shows the curve of average amounts of nitrates to a depth of 2 feet in the fallow plat, the average soil-moisture curve to the same depth, and the precipitation curve. It is evident that neither the soil-moisture curve nor the precipitation curve shows any close agreement with the nitrate curve. The moisture curve is nearly straight, varying only from 24 to 29 per cent during the whole season. The other two curves parallel from June 19 to the end of the season, but as the formation of nitrates had already taken place and as the amounts thereafter remained constant, it is likely that this agreement is only incidental. It might be mentioned, incidentally, that the mean temperature of the air did not reach nearly its maximum until some time later than June 19; in fact, the maximum temperature occurred in September.

In figure 6, which gives the corresponding data obtained on the wheat plat, there is a closer relation between the moisture and the nitrate curves, but as the growing crop has removed much of the moisture and the nitrates from the soil it is apparent that no close causal relationship could be insisted on in this case either. There is, on the other hand, a close agreement between the moisture curve and the weekly crop-increase curve. The hygroscopic coefficient for this soil is very high (about 12 per cent), and judging from the general appearance of the crop and of the soil at the time it is likely that the moisture curve from the first part of July represents about the minimum to which the wheat plants could reduce the moisture content of the soil, and the same holds true in regard to the nitrate curve, as mentioned earlier. This same removal of moisture would, of course, also check nitrification, so both this and the plant feeding would keep the nitrates from increasing.

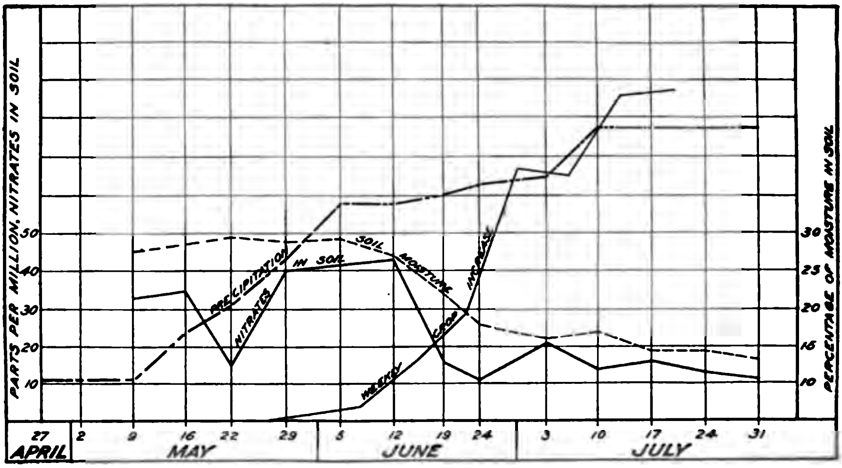

FIG. 6.—Diagram showing the average parts per million of water-soluble nitrates in dry soil to a depth of 2 feet in the spring-wheat plat; also soil-moisture, precipitation, and weekly crop-increase curves.

Figure 7 brings out more clearly than figures 1 and 2 the phenomenon of the general parallelism in the maximum nitrate accumulation in the individual soil layers in the wheat and fallow plats. This figure does not show the absolute amounts of nitrates found in the soil, but shows simply the period during which the respective 6-inch soil layers in the fallow and wheat plats contained an amount of nitrates greater than any other 6-inch layer. It will be noticed that there is a very close agreement between the two plats in the depth at which nitrates were most actively accumulating at different periods and that other factors than cropping evidently determine the seasonal activity of nitrification.

THE DISAPPEARANCE OF NITRATES.

Glancing again at figures 1 and 2 it would naturally be asked what became of the water-soluble nitrates in the individual 6-inch soil layers after accumulation had reached a maximum, and why the seasonal shifting of the maximum amount of nitrates has such a distinct downward movement. It would be expected that the rainfall would tend to wash down the nitrates along with other salts, and such probably did take place to some extent. Selecting the week from May 9 to May 16, in figure 2, there would seem to have been such a movement from the surface layer to the 12-inch layer. The rainfall for that week was 1.25 inches. This is the only instance, however, in the two figures which shows the plausibility of such an explanation of the apparent downward "movement" of the nitrates. Inspecting figure 1, where no growing crop complicates the results, it would even appear that the rainfall had the opposite effect, as, for instance, during the period from May 22 to May 29. The effect seen there could not be explained by the washing down of the nitrates by the rains, as there was an increase in nitrates in all of the soil layers

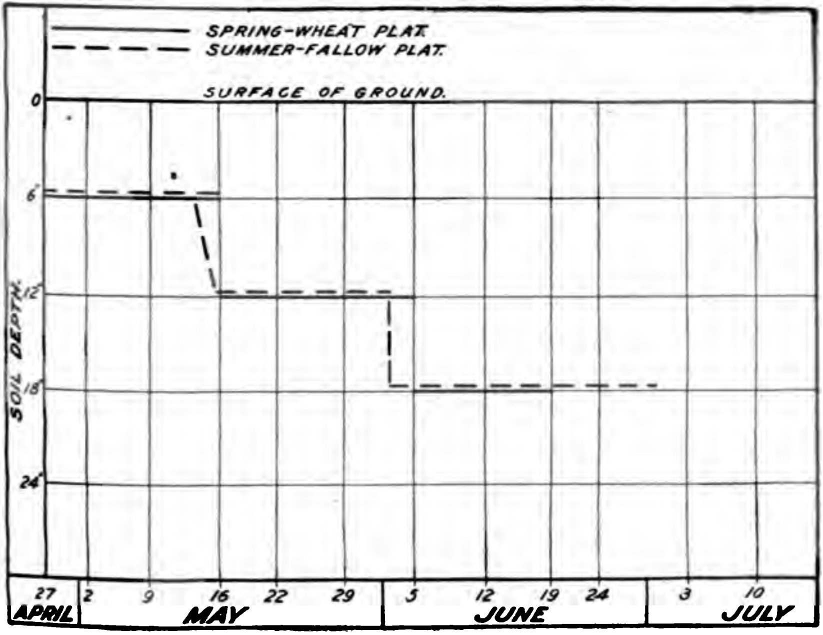

FIG. 7.—Diagram showing the time and location of the maximum amount of nitrates in the wheat and fallow plats.

except the 12-inch layer during that week. The same point i brought out during the period from June 5 to June 12, there bein no rainfall at all to wash down the nitrates from the surface into th 12, 18, and 24 inch layers. And, finally, no such explanation ca be given for the sudden drop in amounts of nitrates during th period from June 12 to June 19, when there was practically no rain

DENITRIFICATION.

At the beginning of the work denitrification was expected to become an obvious factor in affecting the seasonal changes of nitrates in the soil, and ammonification was also expected to become of measurable importance; accordingly, determinations of nitrites and ammonia were made. Neither of these activities, however, assumed any importance at all during any part of the season so far as the analyses brought out, and, accordingly, toward the end of the season ammonia and nitrite determinations were not regularly made—sufficiently often, however (usually every other week), to know the amounts present of these compounds.

No conveniences were at hand for making ammonia determinations directly on the fresh soil, and this is obviously the best way of determining these compounds. The determination of the water-soluble ammonium compounds could not be expected to give reliable data. That ammonia may have been formed in larger amounts than would be suggested by the quantities found during the season would appear from the work of Stevens and Withers,[a] who state that in some soils "nitrification proceeds as rapidly as ammonification, converting the ammonia to nitrate as fast as it is rendered available by the ammonifying organisms."

The amounts of nitrites found varied during the whole season from nothing to 1.8 parts per million in the dry soil. There was no regularity in even these small amounts, one week traces only or none at all being found and the next week traces to 1.8 parts per million. The same irregularities held true in the individual soil layers. The usual amounts of nitrites were from 0.1 to 0.3 part per million, and one single sample—from the 6-inch layer in the wheat plat, on May 22—had 6 parts per million, the only nitrite determination made that exceeded 1.8 parts per million at any time during the season.

The determinations likewise showed the presence of but small quantities of ammonia per million parts of dry soil, but in this case there was a slight decrease toward the end of the season. During the earlier part of the season, the amounts found averaged 6 to 8 parts of ammonia per million and toward the end of the season the amounts fell to about 3.6 to 4.7 parts per million. No such gradual decrease in amounts of nitrites toward the end of the season occurred. The variations in the quantities of ammonia and of nitrites in the individual soil layers were apparently not then sufficient to account for the marked and general and consistent changes observed in the case of the nitrates.

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[a] Stevens, F. L., Withers, W. A., et al. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, pt. 2, 1909, p. 23; abstracted in Experiment Station Record, vol. 21, no. 2, 1909, pp. 118-119.

It may be remarked that although the soil is heavy in texture and likely to compact under bad treatment, the soil on the plats was quite loose and open, it being the first year after breaking. Also, toward the middle of summer the soils cracked quite freely, so that there was fair opportunity for soil aeration all season, and, as the precipitation curve will show, there was no trouble with water-logging of the soil. All conditions considered, it is apparent that conditions were not extremely favorable for active denitrification.

SEASONAL VARIATIONS IN NITRIFICATION.

Referring again briefly to all of the figures, one is struck by the remarkable uniformity of direction of all the curves, especially in figures 1, 2, and 3. The facts that the same general variations exist in all cases and that denitrification is probably not responsible for the nitrate changes point to a general seasonal phenomenon which is affected in degree but not in kind by the presence of the growing crops.

It must be kept in mind that the nitrates found were those soluble in water and that the curves thus represent only the water-soluble nitrates. It would appear that nitrification began earliest in the surface layer of the soil and that the maximum activity of this process gradually extended downward into the successively lower 6-inch layers and reached its maximum in any one layer in general at a period of about two weeks later than in the next 6-inch layer above. In other words, conditions of temperature, aeration, etc., were favorable for nitrification in the surface layer earliest, as would of course be expected, and these favorable conditions obtained later in the lower soil layers. By June 12 these requisite conditions had in general reached their optimum throughout the 2-foot soil section studied, and it might well be conceived that the physiological activity of the bacterial flora necessary for nitrification reached its maximum in the comparatively short period of about two or three weeks in each soil layer after the conditions had once become most favorable and that the general "crop" of nitrifying bacteria matured by the middle of June.

Under this interpretation it would be inferred that the nitrifying bacteria had an active growing season, so to speak, of two to three weeks after favorable climatic conditions had been established and that after this period of growth they underwent a resting period, or at least their physiological activity was much reduced, just as is the case with an annual flora of higher plants. From this explanation one would expect that their general activity would be more intense and begin earlier in the fallow plat than in the wheat plat, as the former was spring-plowed to a good depth, while the latter was not so treated—and this is the case. As already noted, the maximum nitrate content in the respective soil layers occurred in general about one week earlier in the fallow than in the wheat plat, but the general "maturity of the crop," to continue the analogy of the higher flora, was effected at about the same time in the two instances, viz, about June 19. This seasonal decrease in nitrification may also be caused by a decrease in food readily available for the nitrifying organisms. Whether the seasonal variation in amounts of nitrates is due to periodicity of the activity of the nitrifying organisms in the soil, unaffected by any climatic or food factor, or whether it is due to lack of sufficient food for continued activity would be hard to decide from the various curves. As somewhat similar variations may be obtained in the laboratory under controlled food conditions, this factor must be kept in mind. Schneider[a] found that the fixation of nitrogen in the soil was greatly increased by the addition of organic food, as also by the addition of potassium phosphate and of lime; and Bazarewski[b] found that the addition of small amounts of organic food promoted nitrification, but that the addition of larger amounts decreased the activity of the organisms.

Notwithstanding the fact that neither nitrites nor ammonia were ever found in sufficient amounts to account for the actual decrease in amounts of nitrates, other organisms active in the production of these compounds may conceivably have increased vegetatively at the expense of the nitrates already present. Whether the food supply itself could be entirely responsible for the variations in the amounts of nitrates it would be hard to decide, but certainly the prairie soil in question is considered quite fertile so far as the ordinary farm crops are concerned, and the plats on which these determinations were made had never been cropped before.

That this rather definite and comparatively short seasonal period of activity of nitrification has not been limited by lack of moisture in the soil would seem to be indicated by the moisture conditions in the summer-fallow plat. The drying up of the soil in the wheat plat, due to the demands made upon the moisture by the plants, would of itself inhibit nitrification, just as excessive dryness would check the growth of any other plant.

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[a] Schneider, P. Landwirtschaftliche Jahrbücher, vol. 35, sup. 4, 1906, pp. 63-83; abstract in Experiment Station Record, vol. 18, no. 8, April, 1907, p. 722.

[b] Bazarewski, L. von. Nitrification and Denitrification in Soils. Reviewed in Experiment Station Record, vol. 21, no. 1, July, 1909, pp. 20-21.

It seems evident, therefore, that the decrease in amounts of nitrates can not be wholly explained by either moisture content of the soil, denitrification, ammonification, or temperature. A shortage in organic food supply may have been one of the principal causes, but it is also possible that the amounts of nitrates accumulated by the nitrifying organisms would inhibit further increase in these salts. Instances of such inhibition are not uncommon in the case of other bacteria and fungi. It is also within the province of possibility that the nitrifying organisms may have accumulated compounds as by-products other than nitrates and that these compounds might have checked any otherwise possible increase in amounts of nitrates. Even when all these factors are considered there would appear to be a rhythmic periodicity of nitrifying activity during the season due to some unknown property of the bacteria.

CHANGE OF WATER-SOLUBLE NITRATES TO ALBUMINOID NITROGEN.

The disappearance of the water-soluble nitrates does not by any means indicate that the nitrogen was actually lost from the soil, but that it was perhaps converted into albuminoid nitrogen by other groups of bacteria. It is quite conceivable that the food requirements might be sufficiently different for the two groups to permit a considerable decrease in the activity of one group and at the same time increase the activity of another group. It may very well be that the artificial application of a food supply suitable for use by the nitrifying organisms would again increase their activity to a point beyond that which they formerly had reached. It is likely that had water-insoluble nitrogen been determined in the same soil series, no general decrease would have been found in this from June 12 to June 19; on the contrary, there would probably have been an increase. In this connection it may be mentioned that Montanari[a] found least amounts of "nitric nitrogen" in February, March, and June, and most in July and August. He found that plats growing wheat, rape, and corn contained more nitrates in the lower stratum (10 to 20 centimeters) than in the upper (0 to 10 centimeters); on a plat growing Medicago, however, this relationship was reversed. This accumulation of the (probably) albuminoid nitrogen would very possibly be of use to plants the following spring and would simply be held in reserve in the soil and either break down into readily water-soluble forms or in other ways become available for use by higher plants. Whitson,

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[a] Montanari, C. Quantity of Nitric Nitrogen in Soils Variously Cultivated. Le Stazioni Sperimentali Agrari Italiane, vol. 41, 1908; abstract in Experiment Station Record, vol. 20, no. 8, March, 1909.

Stoddart, and McLeod[a] found that the difference in the amount of nitrogen between virgin land and cropped land was not enough to account for the crops removed, and they suggest that this fact is due to the removal of nitrogen by bacteria. Their work was carried on in humid regions, however, where leaching would affect the distribution of nitrogen in the soil.

In an area such as the prairie region represented, where the amount of rainfall is rather limited, there would be an accumulation in the fallow plat of both water-soluble and albuminoid nitrogen. The crop would have the advantage of the nutritive condition of the soil solution represented on July 31 in figure 1, as compared with the less favorable conditions obtaining on April 27 in figure 2.

It should be kept in mind that the plats on which the determinations were made were "dry farmed," and it is not intended strictly to apply to irrigated lands the conclusions derived from this work. Irrigation would in all probability cause disturbances in the bacterial processes in the soil, and so, to some extent at least, mask the seasonal activities of the bacterial flora by translocation of the nitrates and by intermittent wetting and drying. It is likely, however, that by properly controlling the work the same general phenomena would be observed.

RELATION OF NITRIFICATION TO SUMMER FALLOW.

As will be noticed from figure 3, the summer-fallow plat contained on July 31 about 35 parts per million more of water-soluble nitrates than did the wheat plat, which would present a more favorable nutritive condition than found in the cropped plat. In view of the fact, however, that the fundamental phenomena underlying nitrification are the same in both the cropped plats and the fallow plat, it would seem that summer fallow would be of doubtful economic value so far as the use of nitrates is concerned. The various curves distinctly show that nitrification is affected in degree but not in kind by the presence of a growing crop, and it is certainly likely, with this point in view, that nitrates were formed to as large an extent in the wheat plat as in the summer-fallow plat; interest on the investment would be lost from the fallow land while lying idle, when by suitable treatment of the soil use could as well be made of the products of the nitrifying organisms each year as to allow the land to lie idle. The bacterial groups active in producing soluble nitrates and albuminoid nitrogen, feeding largely on the organic matter in the soil, would of course reduce their food supply more rapidly in a system of fallowing than in a system of crop rotation, where organic matter is continually being added to the soil. Another serious objection to summer fallowing, aside from the one just mentioned, is the fact that favorable conditions for chemical oxidation of the organic matter obtain because of the more ready access of heat to the soil due to its exposed condition. So in an area such as is represented by this station where even so far as moisture is concerned fallowing is questionable as a system, the nitrifying flora would be served better by eliminating fallowing.

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[a] Whitson, A. R., Stoddart, W. C., and McLeod, A. F. Twenty-Third Annual Report, Agricultural Experiment Station of the University of Wisconsin, 1906, pp. 160–170.

SUMMARY.

In the early part of spring the surface 6 inches of soil contained more water-soluble nitrates than the lower 6-inch layers, and the amount reached its maximum in the first layer in the first and second weeks in May.

From that time the amounts of water-soluble nitrates decreased in the surface layer, and at the same time the nitrates in the 12-inch layer increased rapidly for one to two weeks, when a decrease was in turn shown in that layer; similarly with the 18-inch and 24-inch layers.

Thus the successive 6-inch layers from the surface 6-inch layer downward, at periods of about two weeks apart, each contained more water-soluble nitrates than any other layer at the same date, and each layer after accumulating a maximum amount showed a decided decrease, which it never again made up.

An exception was the 24-inch layer, which, while it showed the same phenomenon as distinctly, did not at any time accumulate more nitrates than any other layer, but underwent the same general changes as the upper layers.

The respective soil layers in the fallow plat reached their individual maximum accumulation of nitrates about a week earlier than the corresponding layers in the wheat plat. From June 12 to June 19 all soil layers in both plats suffered a general decrease in amounts of water-soluble nitrates. This occurrence took place in the spring-wheat plat in the same order and in about the same magnitude as in the fallow plat.

No evidence could be brought out that the wheat-plant roots drew more heavily on the water-soluble nitrates in one 6-inch soil layer than in any other at any time. The general decrease of nitrates in all of the soil layers in the fallow plat masked any such reduction by the wheat if any occurred.

The corn plants at the end of their most active season of growth had reduced the amounts of water-soluble nitrates in the soil to the same degree of exhaustion as had the wheat plants in the corresponding period of their development. The roots of the corn plants probably used the nitrates in the surface soil layer first, then drew most heavily upon the 12-inch layer, and finally upon the 18 and 24 inch layers. This progressive downward feeding of the corn roots occupied the time from June 19 to July 17; at the latter date the nitrates had probably been reduced by the corn roots to the lowest limit possible.

The wheat and corn plants reduced the nitrates to a constant amount—about 15 parts per million in the dry soil. The wheat removed the moisture also to a fairly constant degree, namely, about 15 per cent.

Denitrification, as measured by the nitrites found, could not account for the changes occurring in the nitrate content in the soil layers.

No correlation could be established between the amounts of nitrates and the air temperature or between the nitrates and the soil moisture.

Translocation of the nitrates by rain could not account for the seasonal changes in the amounts of nitrates in the different soil layers.

The general increase and decrease in water-soluble nitrates followed the same course in the fallow plat and in the cropped plats, the only general difference being that there were more nitrates in the fallow plat after May 16 than in the wheat plat.

It is suggested:

(1) That the marked increase in the amounts of water-soluble nitrates in the individual soil layers, followed by marked decrease in the same, and not at any time again reaching the same quantity, is due to a seasonal physiological activity of the bacterial flora, depending upon the climatic and nutritive factors in the soil, or else the seasonal changes are due to a rythmic periodicity of activity in the nitrifying organisms during the season, the nature of which could not be made clear by the data obtained.

(2) That the general decrease in amounts of water-soluble nitrates from June 12 to June 19 may be due to the formation of albuminoid nitrogen by other groups of bacteria which may have become most active at this time; that the excessive accumulation of nitrates or the accumulation of other by-products by the nitrifying organisms may have inhibited further activity on their part.

(3) That, while the summer-fallow plat contained at the end of the season more water-soluble nitrates than did the corn and wheat plats, the same general phenomena of nitrification are found to take place in both fallow and cropped plats; hence the extended practice of summer-fallowing would seem to be of doubtful value so far as the accumulation of nitrates in the soils represented by this station is concerned.

NOTE.—Since this bulletin was put into type, a review of Kansas Station Bulletin 161, appearing in the Experiment Station Record, vol. 22, no. 1, p. 21, gives as one of the conclusions arrived at by the authors, that "bacterial life and activity seem to rise and fall with more or less regularity. These periods of maximum and minimum activity are to a certain extent independent of moisture and temperature, and are possibly due to the presence of bacterial by-products." This conclusion corresponds closely with the work herein described and shows that other bacterial groups besides the nitrifying flora have the periodicity mentioned in this bulletin.

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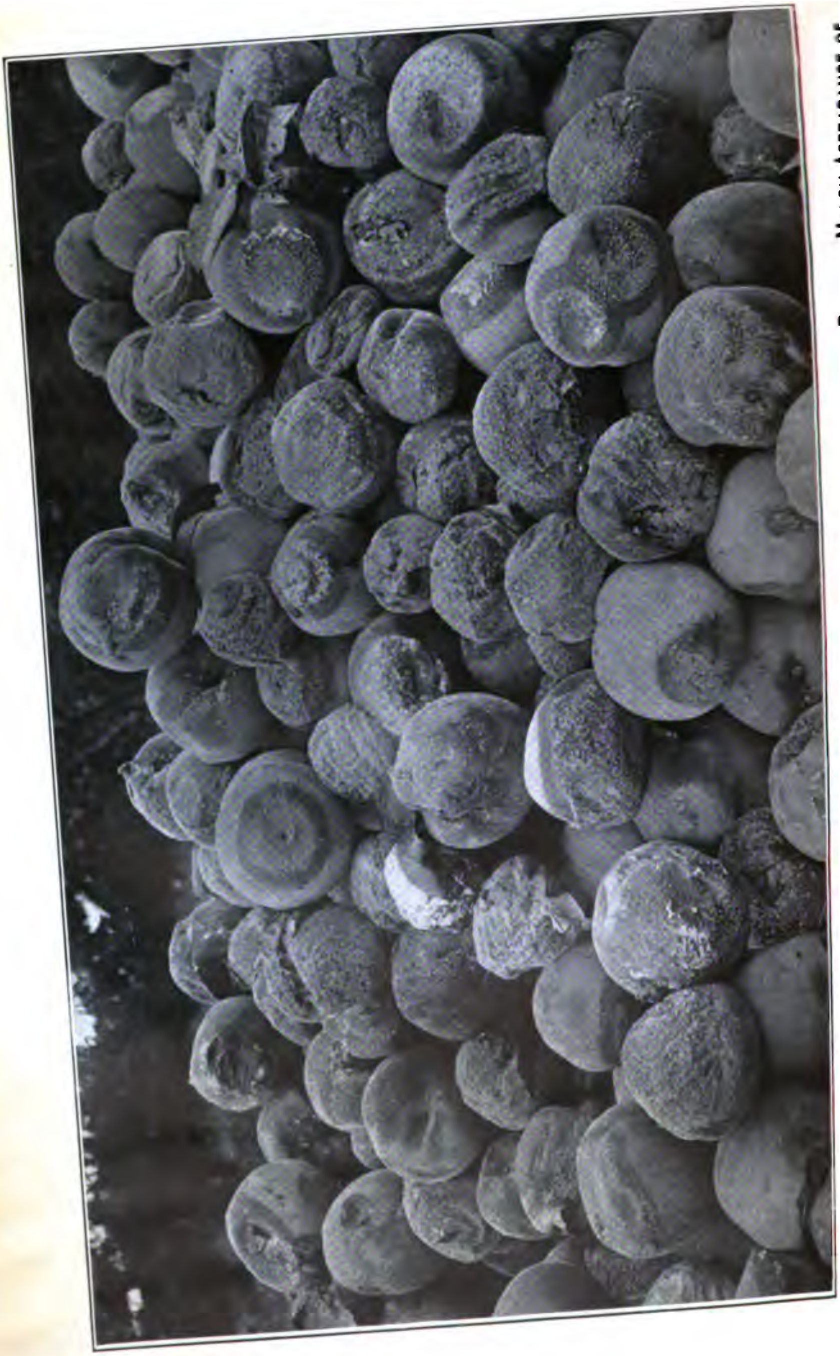
PLATE I.



Peaches Affected with Brown-Rot, Showing the Destructive Work of the Disease and the Rotten, Moldy Appearance of the Fruit.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 174.

B. T. GALLOWAY, *Chief of Bureau.*

THE CONTROL OF PEACH BROWN-ROT AND SCAB.

BY

W. M. SCOTT, PATHOLOGIST,

AND

T. WILLARD AYRES, SCIENTIFIC ASSISTANT,

FRUIT-DISEASE INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 15, 1909.

Sir: I have the honor to transmit herewith a manuscript entitled "The Control of Peach Brown-Rot and Scab," by Mr. W. M. Scott, Pathologist in Charge of Orchard Spraying Experiments and Demonstrations, and Mr. T. W. Ayres, Scientific Assistant, Fruit-Disease Investigations, and recommend it for publication as a bulletin of the special series of this Bureau.

The summer spraying of peaches has for years been a puzzling problem on account of the injury to the foliage resulting from the use of various mixtures. After repeated trials a fungicide was found in 1907 in the form of self-boiled lime-sulphur which prevents diseases without injury to the foliage.

The experiments with this material were repeated on a larger scale in 1908. During the past season (1909) the treatment was demonstrated on a block of 5,000 trees and further details were worked out by experiment. The present paper describes these demonstrations and experiments and gives a summary of the three seasons' work, with recommendations for the treatment of orchards.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CONTROL OF PEACH BROWN-ROT AND SCAB.

INTRODUCTION.

The susceptibility of peach foliage to injury from applications of the usual copper fungicides has largely prohibited summer spraying for the control of peach diseases. The diseases preventable by dormant spraying, such as leaf-curl and the California peach blight, have been easily overcome, but those requiring summer treatment have, as a rule, been allowed to go unchecked for the want of a suitable fungicide. The peach has therefore largely had to fight its own battles against some of its worst enemies, with the result that the growers of this fruit have annually sustained heavy losses.

During the past few years the Bureau of Plant Industry has endeavored to develop a fungicide that could be safely used on the peach during the growing season to prevent some of the diseases of the fruit and foliage. Various copper compounds in both liquid and dust form were tested without satisfactory results. Experiments with sulphur in various forms showed that the soluble sulphids were even more caustic than Bordeaux mixture, and no encouragement was obtained from the work until the so-called self-boiled lime-sulphur mixture was tested.

In the experiments of 1907, the results of which were published in Circular No. 1 of the Bureau of Plant Industry,[a] it was found that self-boiled lime-sulphur could be used as a spray on the peach without injury to fruit or foliage. Brown-rot infections were held down to 10 per cent of the crop, while 73 per cent of the fruit on the unsprayed trees rotted. The same treatment prevented the peach scab, or black-spot, and some leaf diseases.

Experiments conducted by the writers during 1908 at Marshallville, Ga., Bentonville, Ark., and Neoga, Ill., verified the previous year's results and gave sufficient data to warrant the recommendation of this mixture for general use in peach-growing districts where brown-rot and scab are prevalent. The results of the 1908 experiments, with suggestions for the treatment of brown-rot and scab, were published in Circular No. 27 of the Bureau of Plant Industry.

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[a] These results were first reported by the writer at the Jamestown meeting of the American Pomological Society, September 25, 1907, and were published in the proceedings of that meeting. They were also presented before the Missouri State Horticultural Society, December 5, 1907, by Mr. F. W. Faurot, who assisted in the work.

During the past season (1909) the work on this important problem was carried out on a large scale somewhat in the nature of a demonstration. The results of this work, together with directions for preparing and applying the mixture for the treatment of brown-rot and scab, are presented in the following pages.

The peach grower now has at his command an effective weapon with which to combat two of his worst fungous enemies—brown-rot and scab. In view of the excellent results obtained from the experiments of the past three years, the writers are of the opinion that self-boiled lime-sulphur will soon become almost, if not quite, as indispensable to the peach grower as Bordeaux mixture has been to the apple grower.

PEACH BROWN-ROT.

HISTORY OF THE DISEASE.

The fungus causing brown-rot was first described by Persoon[a] in 1796 as *Torula fructigena,* and he later transferred it to the genus Monilia. In 1893 Schröter[b] placed the fungus in the ascomycetous genus Sclerotinia, although its perfect stage was not known until discovered by Norton[c] in 1902. The fungus is reported by Saccardo[d] as occurring in Great Britain, Germany, France, Italy, Belgium, and Austria, as well as in the United States. Perhaps the first to recognize it as of economic importance were Von Thümen[e] and Hallier[f] and it has been discussed by Frank,[g] Prilleux,[h] Wehmer,[i] Sorauer,[j] Woronin,[k] Aderhold,[l] and other European writers who have contributed largely to our knowledge of the life history of this fungus.

In the United States this disease has been known for many years and has had more or less attention from nearly all the pathologists of this country. In 1881 Peck[m] gave what appears to be the first economic account of the disease, and since that time it has been the subject of study by a large number of investigators, notably Arthur,[n] Galloway,[a] Erwin F. Smith,[b] Humphries[c] and Quaintance.[d] Various other articles dealing principally with the treatment of this disease have appeared in bulletins of the state experiment stations and of the United States Department of Agriculture, and in agricultural journals.

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[a] Observationes Mycologicæ, vol. 1, p. 26.

[b] Kryptogamen Flora von Schlesien, vol. 3, Pilze, p. 67.

[c] Transactions, Academy of Science, St. Louis, vol. 12, no. 8, 1902, pp. 91–97.

[d] Sylloge Fungorum, vol. 4, 1886, p. 34.

[e] Oesterreiches Landwirtschaftliches Wochenblatt, no. 41, 1875, p. 484; see also Fungi Pomicoli, 1879, pp. 22–24.

[f] Wiener Obst- und Garten- Zeitung, 1876, p. 117.

[g] Krankheiten der Pflanzen, 2d ed., vol. 2, 1896, p. 360.

[h] Maladies des Plantes Agricoles, vol. 2, 1897, pp. 449–453.

[i] Berichte der Deutschen Botanischen Gesellschaft, vol. 16, 1898, pp. 298–300.

[j] Berichte der Deutschen Botanischen Gesellschaft, vol. 17, 1899, pp. 186–189.

[k] Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg, ser. 8, vol. 10, no. 5, 1900, pp. 18–29.

[l] Berichte der Deutschen Botanischen Gesellschaft, vol. 22, 1904, pp. 262–266.

[m] Thirty-fourth Report, New York State Museum, Natural History, 1881, pp. 34–36.

[n] Fourth Report, New York Agricultural Experiment Station, 1886, pp. 281–285.

Hygienic measures, such as the removal of rotting and mummied fruits and the pruning out of diseased twigs, have been strongly recommended for the control of brown-rot, and most writers have advised spraying with dilute Bordeaux mixture; but only in rare instances have these remedial measures been successful. In spite of the fact that in a wet season when treatment is most needed Bordeaux mixture and other copper compounds injure peach leaves and defoliate the trees, nearly all the recent publications on the subject have recommended spraying with these fungicides, the authors believing that the benefit would more than counterbalance the injury.

ECONOMIC IMPORTANCE OF THE DISEASE.

With the possible exception of peach yellows, which kills the tree outright, brown-rot has for years been recognized as the most destructive disease of stone fruits, such as peaches, plums, and cherries. It also affects the apple, pear, and quince, but only in rare cases does it become a serious pest on these pomaceous fruits. The disease is well distributed over the United States, and in most of our humid sections it has practically prohibited the commercial production of the European plum and often destroys a large portion of the crops of peaches, Japanese plums, and cherries. The average annual loss to the peach growers of this country easily reaches $5,000,000. Quaintance[e] estimated the loss in Georgia for the year 1900 at from $500,000 to $700,000. The number of bearing trees in that State has more than doubled since that time and the brown-rot has not abated in the least, so that a conservative estimate of the loss at the present time with a fair crop of fruit set and under average brown-rot conditions would be $1,000,000; in fact, the writers are convinced that the loss during the past season, with only a third of a crop, almost reached that figure. Similar losses occur in other Southern States, and the more northerly peach districts are by no means exempt. Dr. Erwin F. Smith[f] placed the loss on the Chesapeake and Delaware peninsula in 1888 at 800,000 baskets (of five-eighths of a bushel), worth $400,000, which he considered a very conservative estimate. The same writer states that the following spring (April and May, 1889) this section experienced an outbreak of the brown-rot on the blossoms and young fruits which destroyed the greater part of the peach crop in four counties, resulting in a loss of at least 500,000 baskets.

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[a] Report, Commissioner of Agriculture, 1888, pp. 349–352.

[b] Journal of Mycology, vol. 5, no. 3, 1889, pp. 123–134; also vol. 7, no. 1, 1891, pp. 36–39.

[c] Eighth Report, Massachusetts Agricultural Experiment Station, 1891, p. 213; also Botanical Gazette, vol. 18, 1893, pp. 85–93.

[d] Bulletin 50, Georgia Agricultural Experiment Station, 1900, pp. 237–269.

[e] Bulletin 50, Georgia Agricultural Experiment Station, 1900, p. 245.

[f] Journal of Mycology, vol. 5, no. 3, 1889, pp. 123–134.

Dr. C. P. Clinton[a] reports that in Connecticut "brown-rot of peaches and plums is always present at harvest time, some seasons becoming so prevalent that it sweeps away a large part of the profits in a few days." The same may be said of the prevalence of this disease in Michigan, Missouri, Arkansas, and in other peach-growing States.

In California, Prof. Ralph E. Smith[b] reported that during 1905 and 1906 the brown-rot was "quite abundant and destructive on apricots, some plums, and early peaches, especially near the coast." It has also been reported from Oregon by Prof. A. B. Cordley[c] as causing excessive rotting of plums in 1897 and 1898 and to a less extent affecting peaches.

The effect of this disease does not cease with the fruit growers, but is felt by the transportation companies, the commission men, and the consumers. Although the fruit may be carefully sorted at the packing house and only sound specimens packed, the disease often continues to develop en route to market, especially if the refrigeration is not good. In an orchard where the disease is prevalent, the healthy fruits easily become contaminated through handling by the pickers and packers, and enough moisture develops in the car through the "sweating" of the fruit to germinate the spores. It thus not infrequently happens that peaches from the Southern States reach the market "specked" and must be sold at half the value of sound fruit. The commission man is often blamed by the shipper for the low returns received, when the trouble is really due to brown-rot. On several different occasions the senior writer has been in the New York market when from thirty to over a hundred cars of southern peaches were sold from 2 to 6 o'clock in the morning and 25 to 50 per cent of the fruit from a large number of these cars was found to be affected with brown-rot. In recent years this condition has so often prevailed that the board of health of New York City deemed it necessary to designate a special health officer whose duty is to inspect the fruit as it is unloaded from the cars and prohibit the sale of such as is badly affected with brown-rot. Fruit arriving in poor condition demoralizes the market to such an extent that where 50 cars of sound peaches may be readily sold at good prices 15 or 20 cars of fruit specked with brown-rot are sufficient to create a "glut" and often bring scarcely enough to pay expenses.

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[a] Report, Connecticut Agricultural Experiment Station, 1903, p. 286.

[b] Bulletin 184, California Agricultural Experiment Station, p. 248.

[c] Bulletin 57, Oregon Agricultural Experiment Station, pp. 3-5.

NATURE OF THE DISEASE AND THE FUNGUS CAUSING IT.

Brown-rot is a fungous disease which affects the fruit of the peach, causing it to decay on the trees or en route to market. As already stated, it is caused by a fungus whose botanical name is *Sclerotinia fructigena* (P.) Schröt. Many fruit growers call it Monilia, the name given to the summer stage of the fungus before the perfect form was known. The fungus also attacks the blossoms and twigs, thus often destroying a portion of the fruit crops at blooming time. The diseased blossoms turn brown and become dried, adhering to the twigs for some weeks. The fungus may extend from the dead blossom into the bark, forming a small brown canker which frequently girdles the twig. In low, damp situations, especially in a wet spring, many blossoms and fruit-bearing twigs may thus be destroyed. Some of the green fruits may become affected at any time during the season, and even young peaches half an inch or less in diameter may rot, but as a rule no serious outbreak occurs until the fruit is nearing maturity. It is at harvest time ordinarily that the greatest destruction is wrought.

On the fruit, brown-rot may at first be observed as a small circular brown spot, which under favorable conditions rapidly enlarges, until within two or three days the entire peach goes down in decay. While the spot is yet small, whitish tufts of spore-bearing threads begin to appear. As the spot enlarges, these tufts, arranged more or less in concentric rings, become so numerous as nearly to cover the surface, giving the diseased area a grayish, moldy appearance. (See Pl. I.) Most of the rotten fruit drops to the ground, but a considerable portion of it may shrivel up on the tree and remain attached until the following season. As in the case of diseased blossoms, the fungus may extend from the rotting peaches into the twigs, killing them and thus reducing the prospects of a crop the following year. In a wet season some varieties suffer so badly from twig infections that the trees have the appearance of a pear tree attacked by blight.

The fungus passes the winter in the mummified peaches hanging on the trees, as well as in those that have fallen to the ground. During the spring and summer, especially in wet weather, the fungus in these mummies produces large crops of summer spores for the infection of the new fruit crop. In the mummies on the ground the fungus forms a black leathery sclerotium, which is the foundation of another kind of spore production. In the spring, during the blooming period, small, brown cup-shaped bodies (apothecia), resembling toadstools, about one-half inch in diameter, are produced from mummies which have remained on the ground through two winters partially or entirely covered with soil. (See fig. 1.) One mummy may produce ten to fifteen of these bodies, each of which produces myriads of ascospores. When disturbed by a puff of wind a little cloud of spores may be seen to rise into the air from one of the cups. These ascospores, as well as the conidia, serve to infect the blossoms. A crop of summer spores is in turn produced on the diseased blossoms and some of the young, green fruits become infected by these, so that there is usually a great abundance of material ready for the infection of the mature crop of fruit, even if the old mummies have been removed from the trees.

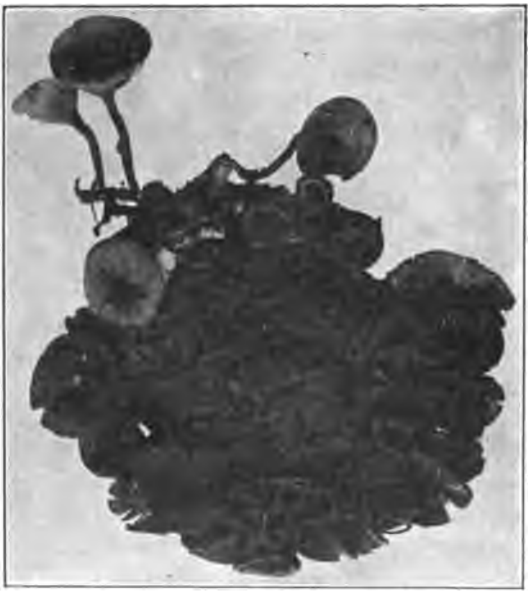

FIG. 1.—An old brown-rot mummy with the cup-shaped bodies (apothecia) of the fungus, in which myriads of ascospores are produced.

It has for years been recommended that the rotten fruit be picked from the trees and from the ground and destroyed in order to remove the source of infection for the following year's crop. This is a good practice, but it is usually disappointing, because the fungus is so prolific in spore production that the few mummies that inevitably escape the pickers are sufficient to furnish the initial infection material for the entire crop of the following year. Protection of the fruit by spraying appears to be the only satisfactory means of combating this fungus, although the destruction of diseased fruits doubtless aids in checking it and should not be discouraged.

INFLUENCE OF THE WEATHER.

Most parasitic fungi are influenced by weather conditions. This is especially true of the brown-rot fungus. Moisture not only favors the growth of the fungus and the production and germination of the spores, but it also renders the fruit tender and watery and therefore more susceptible to rot. In a dry season, or one with only occasional rains of short duration, a peach crop may be expected to reach maturity practically free from rot, particularly if the weather is cool; but when a series of cloudy days with frequent showers occurs about picking time, half or even all of the crop may be destroyed by brown-rot. Prolonged cloudy, drizzly weather, even though the precipitation may not be great, is far more dangerous than a heavy rain followed by clearing. Hot weather also favors the rapid growth of the fungus and increases the danger of its destroying the crop.

INFLUENCE OF INSECTS.

The spores are undoubtedly distributed broadcast by the wind, so that they are in most cases ever present on the fruit ready to produce an outbreak of the disease when the conditions are favorable. Although the fungus appears to be able to enter the peach through the unbroken skin, entrance is more readily accomplished through abrasions such as are made by insects and through cracks due to the scab fungus. Sucking insects of the squash-bug family (Coreidæ) have been observed to puncture healthy and diseased fruits indiscriminately,[a] thus not only distributing the spores but probably inserting them into the peach. But the curculio is by far the worst offender. It breaks the skin of the peach and leaves a wound through which the fungus readily gains entrance. Although the wound may apparently heal before an outbreak of rot occurs, an exudation of gum often keeps it open sufficiently to admit the fungus. The work of this insect greatly reduces the efficiency of fungicides applied for the control of brown-rot. It punctures the fruit through the coating of spray, possibly inserting brown-rot spores and certainly leaving an opening for the fungus. In experiments conducted by the Bureau of Plant Industry in cooperation with the Bureau of Entomology it was found that 93 per cent of the brown-rot infections on sprayed fruit had taken place through curculio punctures. It is evident, therefore, that in order to secure the best results from spraying for brown-rot, the curculio must also be controlled.

PEACH SCAB.

CHARACTER OF THE DISEASE.

Peach scab is a disease caused by the fungus *Cladosporium carpophilum* Thüm. It is also known as black-spot, and peach growers often call it "freckles," which is an appropriate name, owing to the freckled appearance the disease gives to the fruit. The spots are dark brown or blackish, circular in outline, and about one-eighth of an inch or less in diameter. They are often so numerous that one side of the peach has a "smutty" or blackish appearance, cracks open, and shrivels. (See Pl. III, figs. 1 and 2.)

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[a] Scott and Fiske. Bulletin 31, Division of Entomology, U. S. Dept. of Agriculture, p. 29.

The disease mars the appearance of affected fruit, reducing its market value and often rendering much of it unsalable. The large cracks which occur in severe cases open the way for brown-rot, and in addition the skin under the individual spots is usually broken, exposing the peach to attacks of the fungus. Preventing the scab is therefore an important step in the control of brown-rot.

The fungus forms brown spots on the twigs where it passes the winter. So far as is known at present, these twig spots are the chief source of infection of the fruit. Fruit infection begins to take place about three to four weeks after the petals fall, although the spots do not show until about three weeks later. Infections continue to take place until about a month before the fruit matures.

ECONOMIC IMPORTANCE OF THE DISEASE.

Peach scab has been known in this country for many years, and it occurs to an injurious extent wherever peaches are grown east of the Rocky Mountains. The damage done by this disease is apparently not fully realized by peach growers. Scab spots are so common on the peach that most of the eastern growers have come to take the disease as a matter of course and scarcely realize that their fruit is bringing 25 per cent less in the market than the same fruit free from scab would bring. Moreover, the fungus has a tendency to dwarf the fruit and prevent it from attaining full size, so that a considerable loss in yield is thus sustained.

On the other hand, some growers recognize it as their worst enemy, and in many localities it practically prohibits the growing of certain varieties. Some of the large orchards in the mountains of West Virginia and western Maryland have sustained heavy losses from this disease, and the growers have been obliged to confine their plantings of such late varieties as Bilyeu and Salway to the high ridges in order to avoid scab. The Bilyeu is very valuable commercially, but the scab has restricted its successful production to the higher points.

It has been known for some years that peach scab could be controlled by applications of Bordeaux mixture, but its use for this purpose has been discouraged by its injurious effects upon peach foliage. The disease has therefore been practically without a satisfactory remedy.

SPRAYING FOR THE CONTROL OF PEACH BROWN-ROT AND SCAB IN 1909.

As stated in the introduction of this paper, peach brown-rot and scab were effectively controlled by spraying with a self-boiled lime-sulphur mixture in experiments conducted during 1907 and 1908. The work of 1907 was confined to small plats in one orchard, while that of 1908 involved several orchards in different localities, aggregating about 2,000 trees.

During 1909, in order to place the treatment on a better commercial basis, large blocks of several different varieties, comprising over 5,000 trees, were sprayed. This was more in the nature of a demonstration than an experiment, although some features of the work were purely experimental, as will be seen in the following pages. In addition to this block, about 7,000 trees in the same orchard were sprayed by the owner under the supervision of the writers.

The work was conducted in the orchard of the Hale Georgia Orchard Company, at Fort Valley, Ga., and the writers are indebted to Mr. J. H. Hale, president of the company, and Mr. J. H. Baird, its superintendent, for their hearty cooperation and valuable assistance. This orchard was in good condition, having been well cultivated, fertilized, and pruned, but in recent years the brown-rot had become exceedingly bad. The crop of 1908 was largely lost on account of brown-rot, scab, and curculio, and the conditions were particularly favorable for a severe test of the self-boiled lime-sulphur treatment. Unfortunately, however, in this orchard, as in most of the Georgia orchards the past season, the crop was very light for all varieties and the yield per tree quite low, but the value of spraying was, nevertheless, strikingly demonstrated.

The spraying was done with a power outfit consisting of a 2-horsepower gasoline engine, a triplex pump, a 200-gallon tank, a propeller agitator, two 25-foot leads of discharge hose, Vermorel nozzles, etc. The mixture was prepared according to the following formula and directions.

PREPARATION OF SELF-BOILED LIME-SULPHUR MIXTURE.

The mixture used in our experiments during the past season was composed of 8 pounds of fresh stone lime and 8 pounds of sulphur (either flowers or flour may be used) to 50 gallons of water. This appears to be about the correct strength, although in mild cases of scab and brown-rot a weaker mixture, containing 6 pounds of each ingredient to 50 gallons of water, may be used with satisfactory results. The mixture can best be prepared in rather large quantities—say, enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur, to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added after first running it through a sieve to break up the lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked, water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

The stage at which cold water should be poured on to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot fifteen or twenty minutes after the slaking is completed, the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. The mixture should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through the strainer.

SELF-BOILED LIME-SULPHUR TREATMENT AND RESULTS.

Several different varieties of peaches were sprayed with good results. The details of the work were about the same in each case, the following notes on the Waddell variety serving as an example of the treatment given and the results obtained:

Plat 1, consisting of 568 Waddell trees, was sprayed with self-boiled lime-sulphur (32-32-200) on April 30, about one month after the petals dropped, and again on May 20, three to four weeks before the fruit ripened. At picking time the entire crop, including dropped fruit from five average trees in this plat, was sorted and counted, with the result that 17 per cent was found to be affected with brown-rot. An examination of the rotting fruits showed that 93 per cent of the infections had taken place through curculio punctures and that aside from such infections only 1 per cent of the crop was affected with brown-rot.

From a commercial standpoint, the scab or black-spot was completely controlled, although 16 per cent of the fruit showed some slight infections. None of the fruit was sufficiently spotted to injure its market value.

Check A consisted of 1,357 unsprayed Waddell trees in a block adjacent to plat 1. Of the fruit from five average trees in this block 49½ per cent was affected with brown-rot and 91½ per cent with scab. About one-third of the scabby fruit, or 28½ per cent of the total crop, was so badly spotted and cracked that it had to be discarded as unmerchantable. In this case 81 per cent of the brown-rot infections had apparently taken place through curculio punctures. In the actual counts of diseased specimens from plat 1, as compared with the unsprayed plat, there was a difference in favor of spraying of 32½ per cent in the case of brown-rot and 75½ per cent in the case of scab. These figures do not tell the whole story. The sprayed fruit was larger, more highly colored, and presented a much better appearance in the package; it carried to the market in better condition and commanded a higher price than the unsprayed fruit.

Plat 2 was a block of 1,275 Waddell trees sprayed only once to determine the value of a single application. The spraying was done on April 30, a month after the petals dropped. The intention was to make this application at a time when it would be expected to accomplish the best results against scab. The Waddell is one of the worst of the early varieties to scab, and to control this disease is an important step in the control of brown-rot.

The sorting record of the fruit from five trees in this block showed that 32 per cent was affected with scab and 12½ per cent with brown-rot. The percentage of scabby fruit ran rather high, but the spots were mostly small and scattered, so that only 2 per cent of the crop was badly affected. If the disease is kept down to two or three spots on each fruit the damage is very slight even though a large percentage of the crop may be so affected. The unsprayed trees of this variety, as pointed out above, had 91½ per cent of the fruit affected with scab, while 28½ per cent of the crop was so badly spotted with the disease as to be unmerchantable. One spraying, therefore, made a difference of 59½ per cent in the amount of fruit affected with scab and resulted in an actual saving of 26½ per cent of the crop from destruction by scab.

COMMERCIAL RESULTS.

In order to determine the commercial results a record was made of the marketable fruit from each plat. The fruit was brought into the packing house, sorted, and packed in the usual way. The number of trees in each plat varied, ranging from 568 to 1,357, and for convenience of comparison the average yield for 500 trees in each plat is given as follows: Plat 1, 160 crates; plat 2, 170 crates; and the check or unsprayed plat, 80 crates.

This record of yield corresponds closely to the results expressed in percentages of diseased fruit as determined by sorting the crop from five trees in each plat. In such large plats considerable variation in the trees and environment would naturally be expected and there was perhaps a sufficient difference between plat 1 and plat 2 to account for the fact that the latter, which was sprayed only once, had less brown-rot and more good fruit than the former, which was sprayed twice. The check plat, which lies between plats 1 and 2, certainly represents something near the average conditions for the whole block involved and the difference in yield between the sprayed and the unsprayed trees was, for the most part, undoubtedly due to the effect of the spraying. The application of self-boiled lime-sulphur, therefore, apparently increased the yield by 100 per cent.

SELF-BOILED LIME-SULPHUR AND ARSENATE OF LEAD IN COMBINATION.

It has been known for many years that the curculio is an important factor in the distribution of brown-rot and that to prevent the former would be an important step toward controlling the latter. In our first lime-sulphur experiments during 1907 the interference of this insect with the efficacy of spraying for the control of brown-rot was again clearly brought out. In discussing the results of that year's work the senior writer stated that "the plum curculio punctures the skin of a certain percentage of the fruit and admits the fungus in spite of all spraying that can be done."[a] Although in most of our experiments the brown-rot has been held down by spraying to about 10 to 15 per cent where the unsprayed fruit ran 50 to 70 per cent of brown-rot, it has nevertheless been apparent in all the work that spraying for brown-rot would not be entirely satisfactory so long as the curculio was not also controlled.

Entomologists have known for many years that the curculio could be controlled by the application of arsenical poisons, but owing to the danger of injury to both fruit and foliage they have very properly been cautious about recommending their use on peach trees. Mr. A. L. Quaintance, of the Bureau of Entomology, during the past five or six years, has experimented extensively on the use of arsenate of lead for spraying peach trees, with the result that a high percentage of curculio injury was always prevented by two or three sprayings beginning soon after the petals dropped. In 1905 he recommended with due caution the spraying of peach trees with arsenate of lead for the control of this insect.[b] Mr. E. P. Taylor,[c] of the Missouri Fruit Experiment Station, recently reported that during 1908 he had obtained a high percentage of fruit free from curculio by the use of arsenate of lead, with very little injury to the foliage. He also noted a very marked reduction of brown-rot on the sprayed trees.

In order to test the practicability of combining arsenate of lead with self-boiled lime-sulphur as a combination treatment for scab, brown-rot, and curculio, one of our principal experiment blocks at Fort Valley, Ga., was devoted to this purpose. This work was carried on in coöperation with Mr. Quaintance. A block of 2,324 Elberta peach trees, 7 years old, was selected for this test and nearly half of it sprayed, the remainder being left unsprayed as a check. The results of the treatment were exceedingly satisfactory, as will be seen in the following notes.

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[a] Circular 1, Bureau of Plant Industry. U. S. Dept. of Agriculture, 1908, p. 16.

[b] Yearbook, U. S. Dept. of Agriculture, for 1905, p. 329.

[c] Journal of Economic Entomology, vol. 2, 1909, p. 156.

The treated portion, designated as plat 6, consisted of 1,100 trees, not quite half of the block. These trees were sprayed as follows:

(1) With arsenate of lead, 2 pounds to 50 gallons of water, on March 31, as the dried calyces (or shucks) were shedding. This application was intended for the curculio only, and as the date was too early for serious brown-rot and scab infection the lime-sulphur was omitted.

(2) With 8-8-50 self-boiled lime-sulphur and 2 pounds of arsenate of lead combined, on April 22, three weeks after the first treatment.

(3) With self-boiled lime-sulphur alone, on May 21.

(4) With self-boiled lime-sulphur alone, on June 9, about one month before the fruit ripened.

The curculio treatment necessitated an extra application before the time to begin using the fungicide, thus increasing the cost. However, the cost of materials, labor, and teams for these four sprayings was only $62.38, or 5⅝ cents for each tree. Moreover, the writers are of the opinion that only three applications, as outlined below, will be required to secure satisfactory results, thus reducing the cost. The trees were watched closely throughout the season and no injury to fruit or foliage was observed.

When the mature fruit, including windfalls, from five average trees in this plat was sorted and counted, it was found that only 4½ per cent was affected with brown-rot, about half of which apparently resulted from curculio punctures. Only 6½ per cent of the fruit showed scab infections, and these were mostly small, obscure specks. The curculio infestation was 27½ per cent of the crop.

The check was composed of 1,224 unsprayed Elberta trees adjacent to the sprayed block. The trees in the two blocks were of the same age and were growing under the same conditions of soil, cultivation, etc., the only difference being that one block was sprayed and the other was not. The fruit from five of the unsprayed trees when sorted proved to be 63 per cent rotten, 99 per cent scabby, and 97½ per cent wormy from curculio. In other words, the crop was practically a total loss. A comparison of these figures with those of plat 6 (the sprayed part) shows that spraying saved 58½ per cent of the crop from brown-rot, 92½ per cent from scab, and 70 per cent from curculio.

COMMERCIAL RESULTS.

A record kept in the packing house showed that the sprayed block of 1,100 trees yielded 327¼ crates of first-class fruit, while the unsprayed block of 1,224 trees yielded only 33¾ crates, all of which were poor in quality. At the beginning of the season the set of fruit appeared to be about equal in the two blocks, but was very light in both. So far as could be determined, the difference in yield was due entirely to spraying. It appears, therefore, that in the combined self-boiled lime-sulphur and arsenate of lead spray we have an effective remedy for the peach scab, brown-rot, and curculio, the yield from the sprayed trees in this instance being ten times that from the unsprayed trees.

MARKETING TEST.

In order to determine the carrying quality and market value of the sprayed as compared with the unsprayed fruit, two cars of peaches from the experiment blocks were shipped to New York, examined on arrival, and sold in the usual way through a commission house. This test was accomplished through the cooperation of Mr. Hale and the Georgia Fruit Growers' Exchange.

The fruit for the first car was picked on Friday, July 9, in a drizzling rain, but was not loaded and billed out until the following day. It was due on the New York market the following Tuesday morning, but was delayed en route and was not sold until Wednesday morning, July 14. This car contained Elberta peaches from the lime-sulphur–arsenate-of-lead block and from the adjacent check block, Belle peaches sprayed three times with lime-sulphur alone, and unsprayed Belles. The market was almost glutted with poor fruit and the prices were at about the lowest point of the season. The fruit was sold at the following prices:

Sprayed Elbertas	$2.00	per crate.
Unsprayed Elbertas	1.50	per crate.
Sprayed Belles	1.25	per crate.
Unsprayed Belles	1.12½	per crate.

The fruit of the second car was picked on Monday, July 12, and was sold on Thursday morning, July 15. This car contained Elbertas sprayed twice and Belles sprayed three times with the self-boiled lime-sulphur; also unsprayed fruit of both varieties. The fruit of this car brought the following prices:

Sprayed Elbertas	$1.45	per crate.
Unsprayed Elbertas	1.25	per crate.
Sprayed Belles	1.50	per crate.
Unsprayed Belles	1.14	per crate.

In the first car the difference in favor of the sprayed fruit was 50 cents a crate for Elbertas and 12½ cents a crate for Belles. In the second car it was 20 cents a crate for Elbertas and 36 cents a crate for Belles. An examination of several crates of Elbertas showed that 34 per cent of the unsprayed fruit was specked with brown-rot, while only 6 per cent of the sprayed fruit was so affected. (See Pl. II.) This difference in market value was due to the fact that the sprayed fruit showed less rot, was more highly colored, and had a better appearance in all respects than the unsprayed fruit. Another significant fact is that in each case all the sprayed fruit was sold before the buyers began purchasing the unsprayed fruit, showing that they readily recognized the superiority of the former. This marketing test indicates that the enhancement in the market value of sprayed fruit would pay the cost of the work several times over.

COST OF THE TREATMENT.

As previously stated, the spraying was done with a gasoline-power outfit of 200-gallon capacity. Three men operating the machine sprayed 900 to 1,000 trees a day. The mixture was prepared in quantities of 32 pounds of lime and 32 pounds of sulphur in a barrel with a small quantity of water, then strained into the spray tank or a supply tank, and diluted to 200 gallons. When the blocks farthest from the mixing platform were being sprayed, a 200-gallon supply tank was used to haul the mixture to the spraying outfit so as to keep the machine in operation and avoid delay as much as possible. One man was required at the mixing station to prepare the mixture, but his time was not entirely occupied in keeping the spraying outfit supplied. In fact, one man should be able to prepare the mixture rapidly enough for five or six spraying outfits.

The quantity of mixture required for each thousand trees varied with the size of the trees. Medium-sized 7-year-old Elberta trees required about 1,400 gallons per thousand for each application. To make that quantity, 224 pounds of sulphur and the same weight of lime were required. The block sprayed with arsenate of lead required 32 pounds of the poison in the first application (when the foliage was scant) and 56 pounds in the second application for each thousand trees.

The price of materials and labor used in the work at Fort Valley, Ga., was as follows: Sulphur (flour), $2.85 per hundred pounds; lime, $1.10 per barrel; arsenate of lead, 12 cents a pound; gasoline, 13 cents a gallon; team (pair of mules), $2.75 a day; and labor, 75 cents a day.

At the above prices the cost of the self-boiled lime-sulphur treatment was 1⅛ to 1⅜ cents per tree for each application, or an average of 4⅛ cents per tree for three treatments. The combination lime-sulphur–arsenate-of-lead treatment cost 5⅜ cents per tree for four applications. Where labor is higher and working hours shorter the cost would of course be greater, but in the South, under conditions similar to those existing at Fort Valley, it appears that the work can be done at a cost of $15 per thousand trees for each application, or $45 for three treatments. This cost is insignificant when considered in connection with the fact that an increased yield of 25 to 50 per cent, or in some cases 100 per cent, may be expected from the treatment.

DANGER OF INJURY TO THE FRUIT AND FOLIAGE.

If the self-boiled lime-sulphur is properly prepared and applied, there is very little danger of injuring the fruit or foliage. In all of our work during the past season not the slightest injury developed on any of the several thousand trees sprayed. During the season the writers examined several orchards, ranging from 200 to 500 acres, that had been sprayed by the owners with self-boiled lime-sulphur. No serious injury had resulted from the spraying in any of these orchards. Where injury occurred at all, it was only slight and was confined to a few dozen trees, except in one case where there was a general scorching of the foliage throughout the orchard, due, perhaps, to too much boiling of the mixture; but even in this case the result was only a slight thinning of the foliage, which was scarcely sufficient to damage the trees. In each case the mixture was so exceedingly successful as a fungicide that the owner did not consider the slight injury caused by it as worthy of consideration. However, of the thousands of orchards that will probably be sprayed with this mixture, there will doubtless occur from time to time cases of rather serious injury. Such cases in the opinion of the writers will be exceptional and will not be so common or so serious as is Bordeaux injury of the apple.

It was expected that where arsenate of lead was used in these experiments some injury might occur, but neither fruit nor foliage showed any signs of injury. In the first application of poison made when the dried calyces were shedding, no lime-sulphur was used, but in the second, three weeks later, the lime-sulphur mixture and arsenate of lead were used in combination. It seems barely possible that the lime-sulphur preparation may correct the tendency of the arsenate of lead to injure, although no definite evidence on this point has yet been obtained. In the experiments conducted at Marshallville, Ga., last year, peach foliage and fruit sprayed with the self-boiled wash and arsenate of lead combined were slightly injured,[a] but the notes on this work indicate that the injury was due mostly to the lime-sulphur wash, which was boiled too long in an effort to get a large amount of sulphur in solution. Some arsenate-of-lead injury will doubtless occur from time to time, but where the curculio is so bad, as in southern peach orchards, it would seem advisable for the owners to take some risk in the use of the poison to hold this insect in check.

DANGER OF STAINING THE FRUIT.

There is some danger of staining the fruit with the mixture if it is applied within two or three weeks of the ripening period. Mr. C. A. McCue,[b] of the Delaware experiment station, reported good results against brown-rot from the use of self-boiled lime-sulphur during 1908, but complained of marring the appearance of the fruit by heavy deposits of lime. The formula that he used (15 pounds of lime and 10 pounds of sulphur to 50 gallons of water) was stronger than necessary, and the spraying was perhaps continued too near the ripening period. In our 1907 experiments this heavy mixture was used and at picking time the fruit was somewhat stained, but the amount of lime used has since been reduced from 15 to 8 pounds in 50 gallons and the staining now is not a serious matter. The Chicago buyers who purchased the sprayed fruit of the orchard at Neoga, Ill., in which our 1908 experiments were conducted, made no complaint of staining, but on the contrary declined to purchase any of the unsprayed fruit on account of bad scab infections. The sprayed fruit of the Georgia experiments showed evidence of the mixture at picking time, but the whitish specks were largely rubbed off in picking, sorting, and packing. It was more highly colored, slightly larger, and presented a much better appearance than the unsprayed fruit. However, in order to avoid whitewashing the fruit, the last application should be made not later than about four weeks before the ripening period and care should be taken to give the peaches a uniformly light coating of fine spray.

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[a] Circular 27, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 6–7.

[b] Bulletin 85, Delaware Agricultural Experiment Station.

RESULTS OBTAINED BY GROWERS IN COMMERCIAL ORCHARDS.

A considerable number of peach growers have already taken up the self-boiled lime-sulphur treatment for the control of scab and brown-rot, and the writers have been able to obtain reports from some of these. Stranahan Brothers, of Bullochville, Ga., were among the first to give it a trial on a commercial scale. In 1908 they sprayed their orchard of 35,000 trees twice with self-boiled lime-sulphur and arsenate of lead. In a letter dated January 13, 1909, they report that, aside from about 50 trees, the leaves of which were slightly burned, "not a leaf or peach was injured and we had no brown-rot and only one-half of 1 per cent of wormy peaches, including culls and drops. In fact, we had no drops, May, June, or otherwise, and had to thin the fruit three times." They sprayed the orchard again in 1909, using about the same treatment, and the junior writer made observations on the results at two different times during the season. It was found that considerable injury to foliage had occurred at several places in the orchard, due perhaps to too much cooking of certain lots, but in no case did this injury appear to be serious, certainly not sufficient to discourage spraying. Peach scab and brown-rot were almost completely controlled, as was the case the previous year.

Miller Brothers, of Okonoko, W. Va., were as quick to take up the treatment, and their work was directed more especially to the control of peach scab. They sprayed their orchard of 600 acres in 1908 and again in 1909 and report that they obtained good results both seasons. In previous years the scab had been so bad that a large percentage of the crop was lost each year, and the owners considered the orchard unprofitable until the lime-sulphur treatment made possible the control of this disease without injury to the foliage.

During 1908 the Sleepy Creek Orchard Company, of Sleepy Creek, W. Va., sprayed their orchard of 15,000 peach trees from three to six weeks after the petals fell with 8–8–50 self-boiled lime-sulphur. A portion of the orchard was sprayed again a month later. Fortunately in this orchard trees were left unsprayed as checks and the difference between the sprayed and unsprayed fruit was so striking that the writers deemed it worth while to sort the fruit from several trees and obtain exact percentages of scab infections. From an Elberta tree sprayed twice there were 1,551 peaches, 15 per cent of which was slightly affected with scab and none badly scabbed. Another Elberta tree sprayed only once had 731 peaches, 44 per cent of which showed some scab spots, but only 1.3 per cent was badly scabbed. (See Pl. IV, fig. 1.) An unsprayed tree in the check block had 468 peaches, all of which were affected and 86 per cent badly scabbed. (See Pl. III, fig. 2, and Pl. IV, fig. 2.) These three trees selected for this count work were situated close together in a rather low place where the scab would naturally be bad. It will be observed that one spraying held the disease in check, so that only a little more than 1 per cent of the crop was badly affected, while 86 per cent of the unsprayed fruit came in this class. However, it would not be wise to conclude from this that one application is sufficient. It is shown that 44 per cent of the fruit sprayed once had some scab infections. The second application reduced this to 15 per cent, none of which was bad. In other words, all of the fruit from the trees sprayed twice was suitable for packing, and none of it had enough scab to attract attention; all but 1 per cent of the fruit from the trees sprayed once was suitable for packing, but had enough scab infections to detract somewhat from its appearance, while 86 per cent of the fruit from the unsprayed trees was entirely unsuited for the market and the remainder was sufficiently affected to decrease its market value.

COURSE OF TREATMENT RECOMMENDED.

Self-boiled lime-sulphur, when properly applied, will entirely control peach scab, and when the curculio does not interfere too seriously it will largely prevent brown-rot. In view of the fact that numerous brown-rot infections take place through curculio punctures, it would seem advisable, where the two troubles occur together, to use arsenate of lead in connection with the lime-sulphur mixture as a combined remedy for both troubles. The fact that arsenate of lead sometimes injures both the fruit and the foliage of the peach is well known and should be borne in mind by the orchardist, but when the applications are made early in the season the danger of injury seems to be slight. Therefore, upon the advice of Mr. A. L. Quaintance, of the Bureau of Entomology, arsenate of lead is included in the course of treatment outlined below.

BROWN-ROT, SCAB, AND CURCULIO TREATMENT.[a]

For the Elberta, Belle, Reeves, and other varieties of peaches of about the same ripening season, the following is advised:

(1) About the time the calyces (or shucks) are shedding, spray with arsenate of lead at the rate of 2 pounds to 50 gallons of water. In order to reduce the caustic properties of the poison, add milk of lime made from slaking 2 pounds of stone lime. The date of this treatment is too early for scab and ordinarily no serious outbreaks of brown-rot occur so early, so that the lime-sulphur may be omitted with reasonable safety; but during warm rainy springs, especially in the South, the lime-sulphur will doubtless be necessary in this application.

(2) Two to three weeks later, or about one month after the petals drop, spray with 8-8-50 self-boiled lime-sulphur and 2 pounds of arsenate of lead.

(3) About one month before the fruit ripens spray with 8-8-50 self-boiled lime-sulphur, omitting the poison.

For earlier maturing varieties, such as Waddell, Carman, and Hiley, the first two treatments outlined above would probably be sufficient ordinarily, but in very wet seasons bad-rotting varieties would doubtless require three treatments. Late varieties, such as Smock and Salway, having a longer season, would not be thoroughly protected by three applications, but on account of the expense the writers dislike to recommend a fourth spraying. In view of the results obtained on mid-season varieties it seems likely that three treatments will ordinarily be sufficient for the late varieties.

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[a] The attention of the reader is called to the following statement by Mr. Quaintance regarding the use of arsenate of lead on the peach for the control of the curculio:

"The schedule of applications, arranged to effect a combination treatment for the plum curculio and brown-rot, represents a compromise as to the number of applications and times of spraying considered strictly from the curculio standpoint. Thus, were the control of the curculio the only consideration, the first application should be made within a week after the falling of the petals; the second about as the dried calyces, or "shucks," are being thrown off by the rapidly swelling fruit, and a third about two weeks later, though this latter treatment is attended with increased risk to the foliage and fruit.

"Of the several arsenical poisons, arsenate of lead should always be employed for stone fruits, especially the peach. There are now numerous brands of arsenate of lead on the market, and while most of these are carefully prepared and ordinarily free from dangerous by-products the grower should exercise care in the selection of a brand, purchasing only from reputable firms. Arsenical injury to peaches manifests itself by a shot-holing and dropping of the leaves and an excessive reddening and sometimes falling of the fruit as it approaches maturity. The extent of injury liable to result will depend upon weather conditions, and the number of applications given. Ordinarily, the risk from two applications of arsenate of lead, as outlined for use with the lime-sulphur mixture, will be inconsequential, and the orchardist can well afford to take the chances of injury in view of the great benefit derived in lessening brown-rot and in the control of the curculio itself."

BROWN-ROT AND SCAB TREATMENT.

In orchards where curculio is not troublesome, the arsenate of lead should be omitted. The treatment for brown-rot and scab on mid-season varieties would then be as follows:

(1) Three to four weeks after the petals fall spray with 8-8-50 self-boiled lime-sulphur.

(2) About three weeks later spray with the same mixture.

(3) About one month before the fruit is expected to ripen make another application of the same mixture.

SCAB TREATMENT.

For the treatment of scab alone, spray the trees with 8-8-50 self-boiled lime-sulphur about one month after the petals drop and again three to four weeks later.

One treatment thoroughly applied one month after the petals drop will so nearly control scab that in many cases a second spraying may not be necessary, but on account of the way spraying is ordinarily done two treatments will usually be required, especially on late varieties.

APPLICATION OF THE SPRAYING MIXTURES.

The necessity of keeping the mixtures thoroughly agitated while spraying can not be too strongly emphasized. Both self-boiled lime-sulphur and arsenate of lead settle readily, and if the spraying outfit is not equipped with a good agitator the mixture will not be evenly distributed and some of the trees will be oversprayed, while others will receive an insufficient application. In power sprayers the propeller type of agitator is the most satisfactory for this work. The early applications of lime-sulphur may be made rather heavy, but the last spraying should be made with fine nozzles, and the aim should be to give the fruit a uniform coating of a mist-like spray. Heavy drenching of the trees should be avoided.

PLATES.

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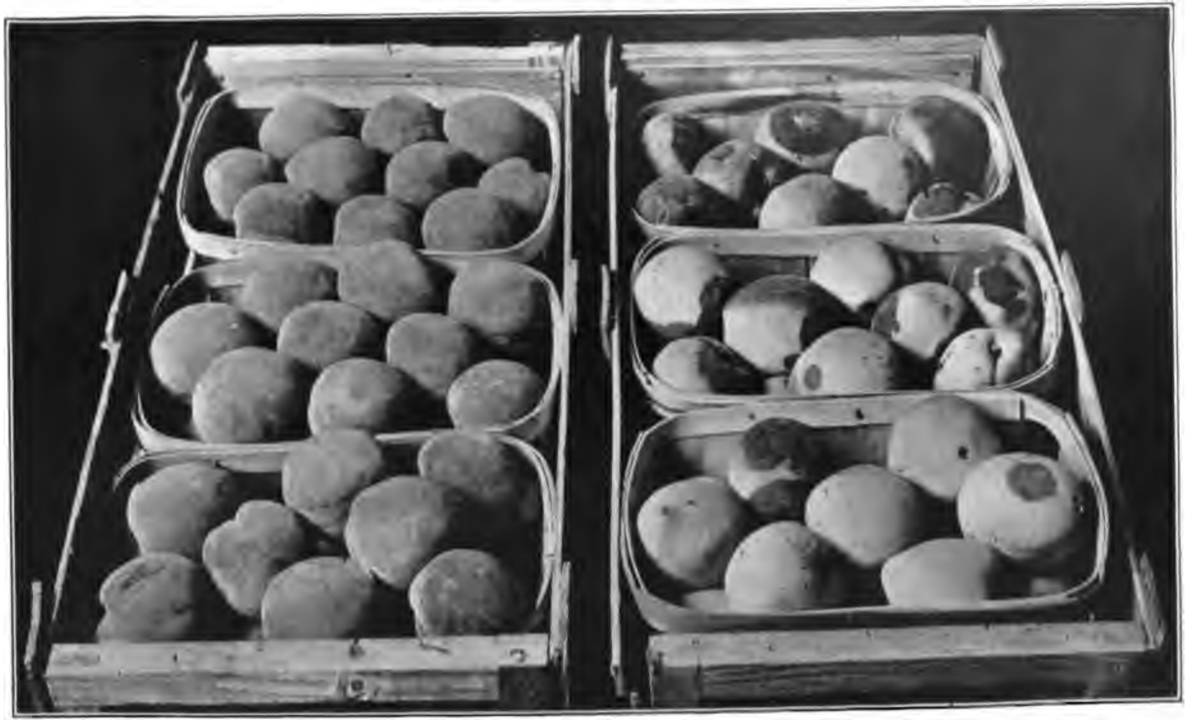
DESCRIPTION OF PLATES.

Plate I. Frontispiece. Peaches affected with brown-rot, showing the destructive work of the disease, the rotten, moldy appearance of affected peaches, and the gray tufts of spores produced by the fungus. This is a photograph of a pile of discarded Carman peaches in an orchard at Fort Valley, Ga.

Plate II. Two crates of Elberta peaches picked from the experimental plats at Fort Valley, Ga., on July 9, 1909, shipped by refrigerator car to New York, and then by express to Washington, D. C., opened and photographed on July 16, a week after picking, showing the difference in the amount of brown-rot developed. The fruit on the left was from a sprayed plat, No. 6, and developed very little brown-rot, while that on the right was from an adjacent unsprayed plat and became badly affected with brown-rot in transit.

Plate III. Peach scab. Fig. 1.—Two unsprayed Elberta peaches affected with scab, showing the black spots and cracks produced by the fungus. Fig. 2.—The crop of peaches from an unsprayed Elberta tree, showing the fruit badly affected with scab. All the fruit was affected and 86 per cent of it was so "smutty" and cracked as to be unfit for the market. This fruit was from one of the unsprayed trees in the orchard of the Sleepy Creek Orchard Company, at Sleepy Creek, W. Va.

Plate IV. Peach scab. Fig. 1.—The crop of peaches from an Elberta tree sprayed once with self-boiled lime-sulphur. The good, merchantable fruit (98 per cent of the crop) is shown in the pile and the unmerchantable, scabby fruit on the notebook at the top. This fruit was grown in the same orchard as that shown in Plate III, figure 2. Fig. 2.—The same unsprayed crop shown in Plate III, figure 2, sorted for the market. The large pile of fruit on the right is unmerchantable on account of scab, that on the left representing all that was suitable or packing (only 14 per cent of the crop).



TWO CRATES OF ELBERTA PEACHES PICKED FROM THE EXPERIMENTAL PLATS AT FORT VALLEY, GA., ON JULY 9, 1909, SHIPPED BY REFRIGERATOR CAR TO NEW YORK, AND THEN BY EXPRESS TO WASHINGTON, D. C., SHOWING THE DIFFERENCE IN THE AMOUNT OF BROWN-ROT DEVELOPED.

The crates were opened and photographed on July 16. The fruit on the left had been sprayed, while that on the right had not been sprayed.

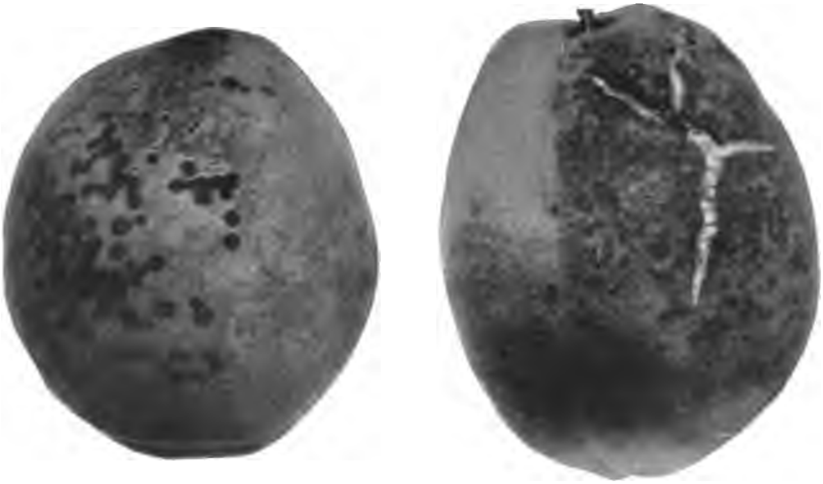


FIG. 1.—TWO UNSPRAYED ELBERTA PEACHES AFFECTED WITH SCAB, SHOWING THE BLACK SPOTS AND CRACKS PRODUCED BY THE DISEASE.

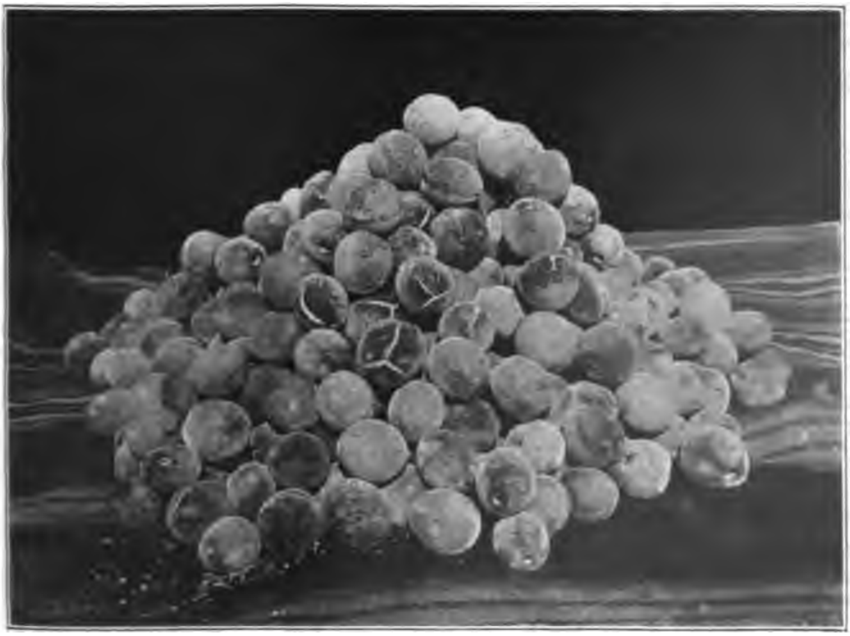


FIG. 2.—CROP FROM AN UNSPRAYED ELBERTA PEACH TREE, SHOWING ALL THE FRUIT AFFECTED WITH SCAB AND 86 PER CENT OF IT UNMERCHANTABLE. SLEEPY CREEK, W. VA., AUGUST 27, 1909.

PEACH SCAB.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 175.

B. T. GALLOWAY, *Chief of Bureau.*

THE HISTORY AND DISTRIBUTION OF SORGHUM.

BY

CARLETON R. BALL,
AGRONOMIST IN CHARGE OF GRAIN-SORGHUM
INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 18, 1909.

Sir: I have the honor to transmit herewith a paper entitled "The History and Distribution of Sorghum," by Mr. Carleton R. Ball, Agronomist in Charge of Grain-Sorghum Investigations, and recommend its publication as Bulletin No. 175 of the series of this Bureau.

The facts stated in the paper have been developed in connection with a study of the agronomic adaptations of over 1,000 varieties of domestic and foreign sorghums. Data concerning the geographical distribution of the sorghum plant and the leading types which are found in different regions of the earth are here presented for the first time. Sorghums have been very extensively used as human food in Africa and the Orient for more than twenty-five centuries. Some of them are now important grain and forage crops in large areas of the western United States, and have been found adapted to a much wider range of climatic and soil conditions than was formerly thought possible. A knowledge of their distribution and adaptations in their native lands will be of value to all agronomic workers and others concerned in the improvement of these crops.

The author wishes to acknowledge his obligation to Miss R. M. Kolck for assistance in the translation of the Latin works; to Miss A. R. Knapp for the translation of the Italian article by Arduino; and to Miss M. F. Warner for aid in securing and citing many old and rare botanical works.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE HISTORY AND DISTRIBUTION OF SORGHUM.

INTRODUCTION.

Certain sorghums now hold a large and increasingly important place as grain and forage crops in the semiarid regions of this country. They were all introduced into the United States between twenty and thirty years ago. Few data were secured concerning their habits and adaptations in their native lands, and many valuable years of time and effort were lost in attempts to grow them successfully in regions to which they were not at all suited.

During the past six years more than 1,200 different lots of domestic and foreign sorghums have been brought together and grown experimentally. By far the greater part of these were from foreign sources—principally from Africa and southern Asia. In most cases only meager information was obtained regarding the conditions under which they had been grown or to which they are most probably adapted in this country. For these economic reasons and because of the bewildering diversity of forms secured it became necessary to inquire at some length into the whole question of the origin and history of this group of cultivated plants. This paper embodies the results of the investigation. The origin and antiquity of sorghums are set forth, together with their present distribution and culture. The chief types or groups now found in each of the major geographical areas are briefly described, the conditions under which they have developed are pointed out, and their probable adaptations in our own land are indicated.

The term " sorghum " is used here in the broad and comprehensive sense. It thus includes all the groups popularly known in this country as sorgo or sweet sorghum, kafir, broom corn, shallu, kowliang, durra, and milo. It covers also an enormous number of cultivated forms in other lands with the possible exception of a few, which, as pointed out in the discussion of botanical history, may perhaps be referred to *Andropogon halepensis* rather than to *A. sorghum*. For the convenience of readers not familiar with the sorghums, a rather full key to the principal groups is inserted here. A complete classification of the domestic varieties is in preparation.

KEY TO THE PRINCIPAL GROUPS OF SORGHUM.

The following is a key to the principal groups of sorghum:

I. Pith juicy.
  A. Juice abundant and very sweet.
    1. Internodes elongated; sheaths scarcely overlapping; leaves 12–15 (except in Amber varieties); spikelets elliptic-oval to obovate, 2.5–3.5 mm. wide; seeds reddish brown. I. *Sorgo.*
  B. Juice scanty, slightly sweet to subacid.
    1. Internodes short; sheaths strongly overlapping; leaves 12–15; peduncles erect; panicles cylindrical; spikelets obovate, 3–4 mm. wide; lemmas awnless. II. *Kafir.*
    2. Internodes medium; sheaths scarcely overlapping; leaves 8–11; peduncles mostly inclined, often recurved; panicles ovate; spikelets broadly obovate, 4.5–6 mm. wide; lemmas awned. VII. *Milo.*
II. Pith dry.
  A. Panicle lax, 2.5–7 dm. long; peduncles erect; spikelets elliptic-oval or obovate, 2.5–3.5 mm. wide; lemmas awned.
    1. Panicle 4–7 dm. long; rhachis less than one-fifth as long as the panicle.
      a. Panicle umbelliform, the branches greatly elongated, the tips drooping; seeds reddish, included. III. *Broom corn.*
    2. Panicle 2.5–4 dm. long; rhachis more than two-thirds as long as the panicle.
      a. Panicle conical, the branches strongly drooping; glumes at maturity spreading and involute; seeds white or somewhat buff. IV. *Shallu.*
      b. Panicle oval or obovate, the branches spreading; glumes at maturity appressed, not involute; seeds white, brown, or reddish. V. *Kowliang.*
  B. Panicle compact, 1–2.5 dm. long; peduncles erect or recurved; rhachis more than two-thirds as long as the panicle.
    1. Spikelets elliptic-oval or obovate, 2.5–3.5 mm. wide; lemmas awned. V. *Kowliang.*
    2. Spikelets broadly obovate, 4.5–6 mm. wide.
      a. Glumes gray or greenish, not wrinkled; densely pubescent; lemmas awned or awnless; seeds strongly flattened. VI. *Durra.*
      b. Glumes deep brown or black, transversely wrinkled; thinly pubescent; lemmas awned; seeds slightly flattened. VII. *Milo.*

AGRICULTURAL HISTORY AND DISTRIBUTION OF SORGHUM.

ORIGIN.

It is generally conceded that cultivated sorghums were originally derived from the well-known wild species, *Andropogon halepensis* (L.) Brot. Prof. E. Hackel (1885) has presented this theory at length, and it is not necessary here to examine his able argument. The wild species is found abundantly in all tropical and subtropical parts of the Old World (fig. 1). It has been quite carefully studied by agriculturists and botanists in India, and to a lesser extent in tropical Africa. Its forms are numerous and the

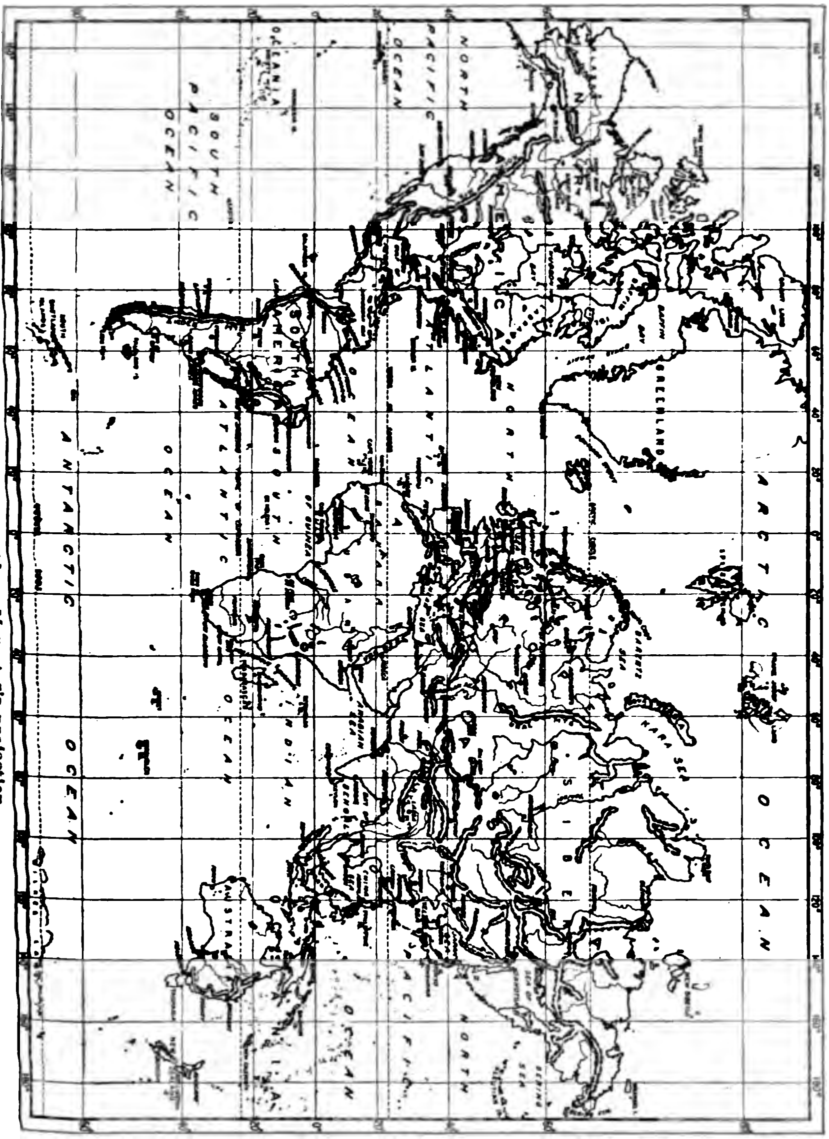

Fig. 1.—Map of the world on Mercator's projection.

main lines of variation are parallel with those represented by the major groups of cultivated varieties. This is especially noticeable in comparing the forms assumed by the wild and the cultivated species in Africa, and to a lesser extent in India also. The abundant variation of the wild species, the great number of different cultivated forms, and, with few exceptions, their evident dissimilarity in the two regions argue for the independent origin of the cultivated species on the two continents. This view has gained wide acceptance in later years. In the discussion of geographic distribution this theory is recognized as the probable one.

ANTIQUITY.

There can be no doubt of the great antiquity of the sorghum plant in cultivation. The story of its domestication is lost in the shadows of the past. From Egypt, the cradle of ancient agriculture, comes the earliest known record of its use. A harvest field frescoed on the walls of the tomb of Amenembes in Beni-Hassan, belonging to a dynasty existing at least 2,200 years before Christ, is said by Wönig[a] (1886) to represent a form of sorghum. This crop is still important in the land of the Nile. In the book of the prophet Ezekiel (600 B. C.) the word "millet" is translated "dochan" ("dochn" or "dokhn") in the original Hebrew text. This word is still used in Arabic for forms of sorghum and also for some of the larger millets, such as pearl millet (*Pennisetum spicatum*). The root word also means "smoke" in Arabic, and the name may be more correctly applicable to pearl millet, with the seeds sometimes smoke colored, than to sorghum. If it here refers to a grain-bearing sorghum, this crop was well known in the fertile and irrigated valleys of the Tigris and Euphrates more than 600 years before the present era. It is known that a sorghum with white and flattened seeds was cultivated in Arabia as early as the tenth century. A very similar white durra is still abundantly grown in Syria and Mesopotamia, and forms a considerable part of the food of the poorer classes.

Little light can be thrown on the early history of sorghum in India. The Roman historian Pliny records the introduction of sorghum into Italy by caravans from India during the first century. How much longer it had been cultivated in India is not certain, nor can we be entirely sure that the record of the Roman historian is correct. Caravans coming from India then, as now, passed through Upper Egypt, and the sorghum supposedly brought from India may possibly have been an Egyptian variety used as food in the last stages of their journey. The great antiquity of sorghum culture in India is, however, assured from other sources. According to Benson and Subba Rao (1906), the plant is mentioned in one tale dating from more than 1,900 years ago. It is spoken of by many other writers of early times and bears a Sanskrit name—Yava-nala (reed barley or reed grain).

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[a] Where only year and page are given, see chronological bibliography at end of bulletin for full citation.

It is very extensively cultivated, with a multitude of varieties and names, throughout the major part of India, especially in the interior in native states, which have had only a limited intercommunication. There are some important religious ceremonies observed in connection with its sowing and harvesting. These facts all point conclusively to its cultivation there from a remote period.

In China there is evidence, according to Bretschneider (1893), that sorghums were first known there in the third century A. D. There are numerous doubtful references of earlier date which may apply either to sorghum or to the true sugar cane. As early as some of the ancient classics there is found mention of a black millet which bore two seeds in each spikelet. So far as the writer is aware, there are no two-seeded varieties known either in *Panicum miliaceum* or in *Setaria* (*Chaetochloa*) *italica*. Several varieties of what may be called "twin-seed" sorghums are known in India. Some of these have black and shining glumes, and it is quite possible that the writer of the ancient classics referred to such forms of sorghum. This is the more probable since it is most likely that China received her sorghum varieties from some part of the Indian Empire.

These isolated records all indicate an early and extensive domestication of this plant. The same conclusion may be deduced from a study of the present distribution of the cultivated varieties.

GEOGRAPHICAL DISTRIBUTION.

Originating in the Tropics of the Old World (fig. 1), sorghums are now grown in the Temperate Zones of both hemispheres. The bulk of the crop is grown between the parallels of latitude 40° north and south. In the United States and in Manchuria the sorghums are found as far north as latitude 45° or more. The two great centers of the cultivation of sorghum for human food are Africa and India. In both regions it is the staple farinaceous food for a considerable part of the population. The distribution of sorghum in India is discussed in its proper order. A word on some of the general aspects of its occurrence in tropical Africa (fig. 2) may be in order before the discussion of individual regions is begun.

The absence of permanent records among the African tribes from the Sahara southward nearly to the Cape makes futile any attempt to study the history of sorghum among them. For many tribes it is, however, the most important food plant and is also commonly used in the manufacture of a fermented drink. The widespread dispersion and cultivation of sorghum among these tribes and their great dependence upon it for food point to its ancient origin and domestication. Still more striking testimony is the extreme richness of the varieties and forms which it presents. These are by no means adequately known, but it seems likely that they will easily outnumber the combined total from all other parts of the world. Most of them belong apparently to groups which are found sparingly or not at all elsewhere. Such a profusion of forms of a cultivated plant among primitive peoples must have required many centuries for derivation and development. Not only the names, but the actual varieties also are often quite different in separate, though adjacent, tribes. The women of a tribe, who are commonly its laborers, often become quite expert in distinguishing closely related varieties—a knowledge to which the men seldom attain. Their methods of cultivation are necessarily crude, but through the accumulated wisdom of many centuries of cultivators they have amassed a great deal of accurate information about the handling of the crop. How it responds on different soils and in different seasons, the proper dis-

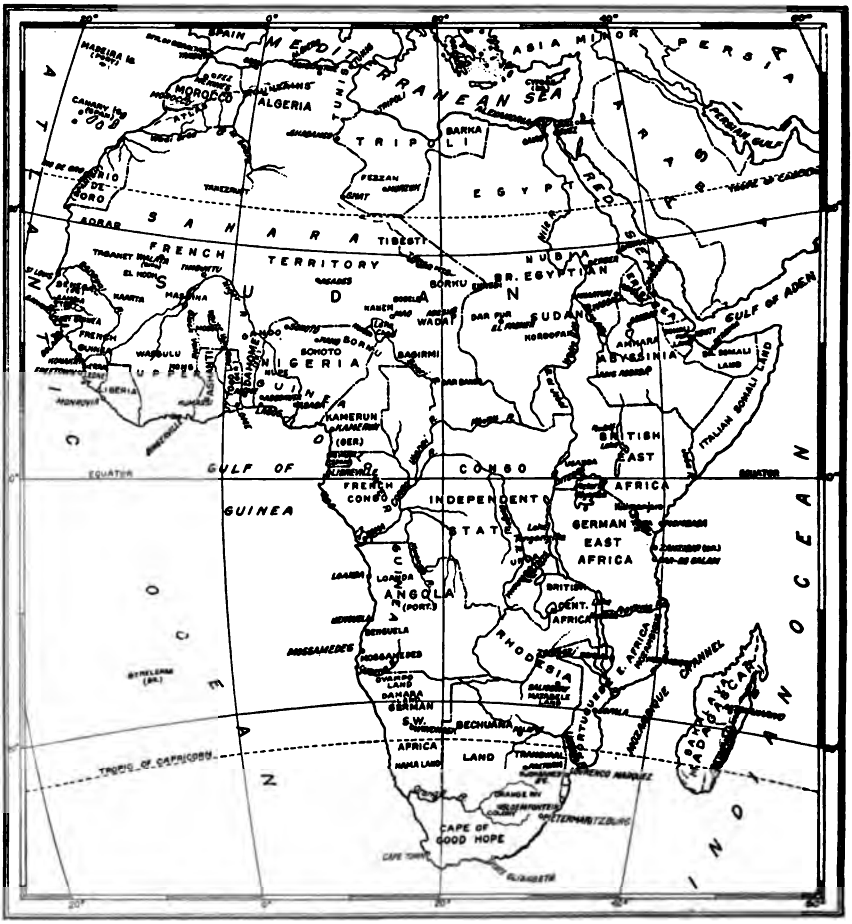

FIG. 2.—Map of Africa. (Scale 1,200 miles to the inch.)

tances for planting the hills of different varieties, how and when to harvest, and how best to cure the seed, as well as considerable skill in preparing different articles of food from it, are matters of common knowledge among the older members of various tribes. Of the numberless varieties grown by tribes throughout the length and breadth of tropical Africa, only the sweet sorghums and kafirs from the region of Natal and the Orange River Colony have ever been brought under cultivation in this country.

SOUTH AFRICA.

That portion of the great tropical continent known as South Africa includes the British areas of Cape Colony, Natal, Orange River Colony, Transvaal, and Rhodesia; also German Southwest Africa and parts of Portuguese East Africa and the Portuguese territory of Angola on the west coast. It is not known if sorghums are grown in the German and Portuguese territory on the west side and little is known of the varieties found in Portuguese East Africa. The forms of British South Africa have been quite fully studied. Much of this area is a more or less dry and elevated plateau, an ideal place for sorghums. Two of the principal groups, sorgos (sweet sorghums) and kafirs, are found here in the greatest abundance and diversity. They require but little selection to make them suitable for use in America because of the similar conditions obtaining in the two regions.

NATAL.

Natal, the smallest division of South Africa, lies in the southeastern part of this great region, its coast washed by the Indian Ocean. Only two sorghum groups, sorgos and kafirs, appear to be native to this little state or extensively grown therein.

In Natal the sorgos are cultivated by the natives for forage and for the sweet juice, which they express by chewing the peeled stalks. It was from Natal that sorgos were introduced to Europe and America. From Natal, Arduino obtained, about 1775, his *Holcus cafer*, which was apparently very similar to our Planter sorgo. From Natal, Wray secured, in 1853, the sixteen saccharine varieties from which have descended most of the sorgos now cultivated in Europe and the United States. Several importations of sorgo varieties were made from Natal in later years, but no systematic comparison of the resulting plants was ever undertaken. It is therefore not known how many different varieties have been found there up to the present time. Some varieties recently obtained are proving distinct from any forms now grown in this country.

The kafir group is probably native in Natal, though the varieties first domesticated in America were brought from the Orange River Colony. Within the past few years forms very similar to our blackhull and red kafirs have been secured in Natal. With these have come a number of other forms varying mostly in the size of the head and in the size and color of the seeds and glumes. Some forms of th Roxburghii group are occasionally found in Natal, but are apparentl introduced from Madagascar, from the regions north of the Zambe River, or from India.

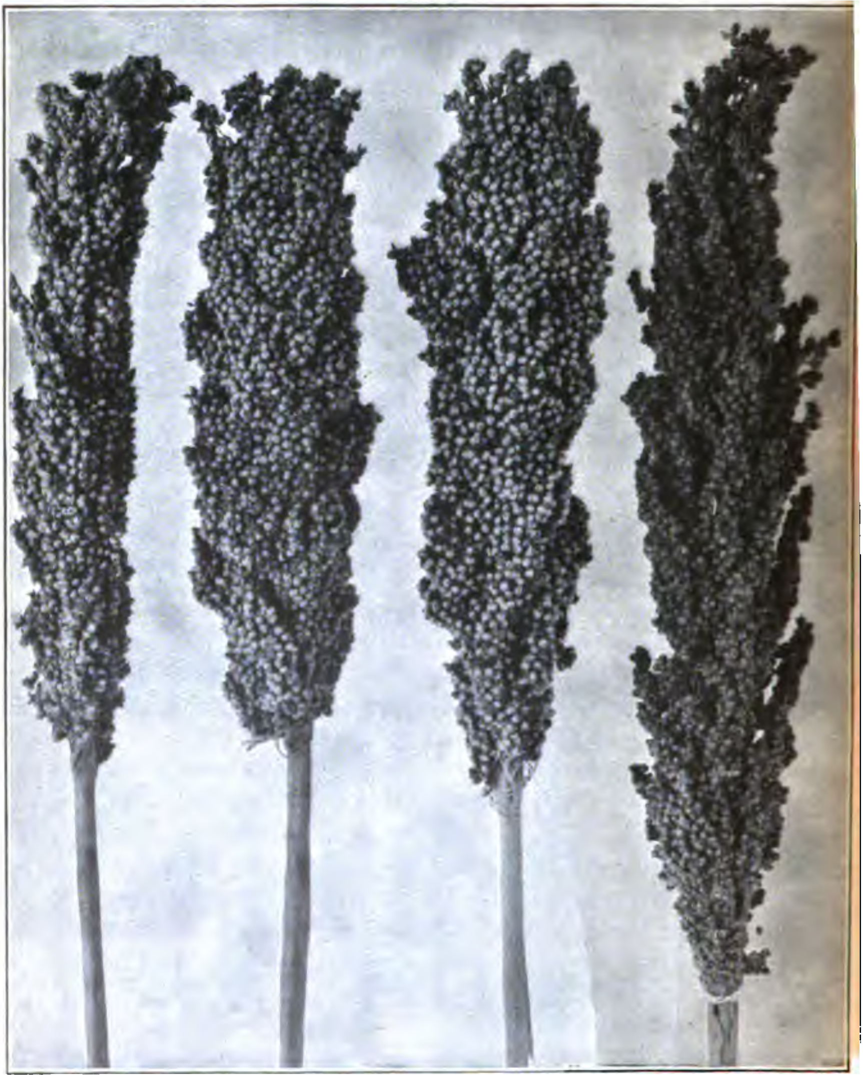

FIG. 3.—Heads of four kafir varieties. *a*, White kafir; *b*, Guinea kafir; *c*, blackhull kafir; *d*, red kafir.

ORANGE RIVER COLONY.

Our widely grown and valuable kafir varieties came from the former Orange Free State about thirty years ago. From that first importation three varieties resulted, the white, the blackhull, and the red kafirs (fig. 3), of which only the last two are now cultivated in the United States. Recent importations from British South Africa, principally from this colony and Natal, reveal the presence of a great number of similar forms throughout the eastern portion of South Africa. They are all undoubted kafirs, differing from our three varieties in minor details, such as size and height of the stalk, length of the head, and size and color of the seeds and glumes. Many of these forms have larger seeds than had the forms first imported. No new colors in seeds have been found, but only varying shades of red and pink. Their variation in much more narrow limits than the sorgos may indicate a more recent origin.

TRANSVAAL AND RHODESIA.

A few kafir forms have recently been obtained from the colonies of Transvaal and Rhodesia. It is probable that when northern Rhodesia has been more fully explored that varieties similar to those of equatorial Africa will also be found.

MADAGASCAR.

The large island of Madagascar, more than a thousand miles long, lies off the east coast of South Africa at a distance of 300 to 500 miles. Its sorghums are naturally not well known, but the few that have been obtained, under the native name of Mpemby, are freely stooling and very leafy sorts, with loose open heads bearing white or reddish-brown seeds. The panicles vary much in shape, some being oblong or narrowly oval, others short and fan shaped, while still others are much elongated and trumpet shaped. The branches of the head are always long, slender, repeatedly divided, and often drooping. (Fig. 4.) The spikelets are slender, acute, and prominently

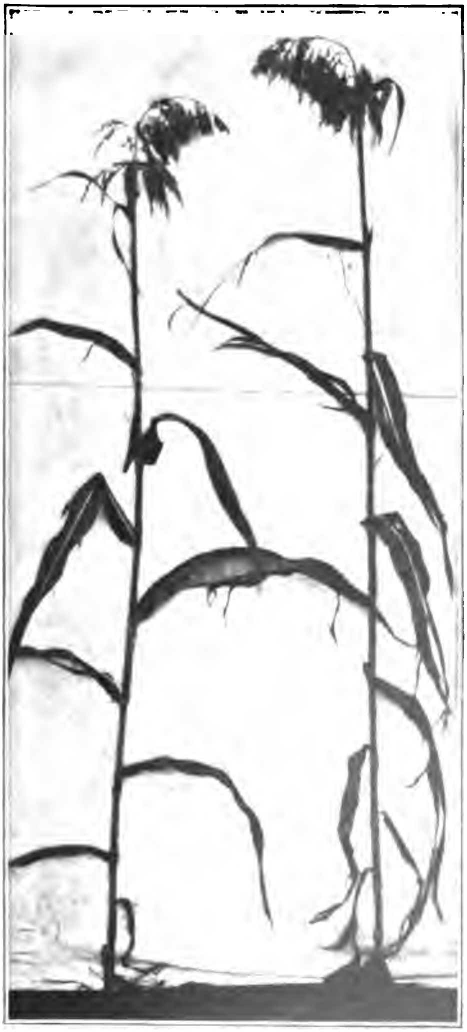

FIG. 4.—Plants of shallu, representing the variety roxburghii, Hackel.

awned. These forms belong, apparently, to the variety *roxburghii* Hackel, together with the shallu of India and some of the forms of the Guinea coast, under which heading this form is more fully described. Similar forms are found occasionally in Natal, where they are apparently introduced rather than native. All these varieties are very late and are apparently adapted only to our Southern States, if at all.

EQUATORIAL AFRICA.

But little is known of the sorghums of equatorial Africa, an immense region which includes roughly about ten degrees of latitude on either side of the equator. They seem to be but little grown in the French and German Kameruns on the west coast. Almost nothing is known of their occurrence in the great interior Kongo State. On the east side, however, it is known that the sorghums occur in extremely numerous and variable forms.

GERMAN AND BRITISH EAST AFRICA.

A considerable number of sorghums have been secured from German East Africa and British East Africa, lying immediately south and north of the equator, respectively. Naturally they have not matured at any of our testing stations in this country, and hence there has been but little opportunity to study them fully at first hand. Many of them certainly represent entirely new groups of sorghum. One of the most promising of these groups stands in some respects in a position intermediate between the sorgos and durras. Some of the varieties represent a northward extension of the kafir group. All are grown for human food and for forage.

SUDAN.

The Sudan has a breadth north and south of about 1,000 miles and an extension east and west of about 4,000 miles. It includes, in its western part, the French Sudan and the numerous small colonies of the Upper Guinea coast. The principal ones of these are, from west to east, Senegal and French Guinea, once known as the Kerry Coast; Sierra Leone and Liberia, the old Grain Coast; the Ivory Coast, now a French colony; the Gold Coast, now a British colony; and finally Togoland, Dahomey, and Nigeria—German, French, and British colonies, respectively, together comprising the Slave Coast. The eastern part of the Sudan is included in the British-Egyptian Sudan, to the east of which lies Abyssinia. The coastal region is tropical and humid, the interior in large part hot and with little rainfall.

FRENCH SUDAN.

Very few sorts have yet been obtained which are known to have come from the interior of the French Sudan. These few do not differ, so far as can be determined by the seeds and glumes, from the groups found farther south in the various colonies of the Guinea coast. However, it seems not improbable that more extensive exploration may discover, in the dry, hot territory forming the southern border of the Sahara, other varieties adapted to our western plains.

UPPER GUINEA.

Varieties have been obtained from Senegal, French Guinea, Ivory Coast, Gold Coast, Togoland, Dahomey, and Nigeria. The leading group is one with large, oval, flattened seeds, varying in color from white through pale red to deep reddish brown; red, brown, or black glumes, and semicompact heads. A striking peculiarity is the lateral rotation of the seed in the glumes at maturity, the axis of the movement being a line from the hilum to the apex of the seed. This movement of the seed is apparently characteristic of the whole group, which includes Hackel's variety *ovulifer* and probably some other botanical varieties. The different forms in this group all have the appearance of being good grain producers. An effort should be made to find some suitable for cultivation in this country. Those heretofore secured are much too late for any but tropical regions.

Another sorghum group found in this region is closely related to the shallu (fig. 4) of India, and probably represents Hackel's variety *roxburghii*. It is characterized by rather slender stalks, loose, open, pyramidal heads with more or less drooping branches, small, oval seeds, and slender, acute glumes, which spread apart and become involute at maturity, completely exposing the seeds. One of these varieties from Senegal, called by the French " Mil Cigne," is apparently meeting with some favor at the Florida Agricultural Experiment Station. It seems adapted as a combined forage and grain crop.

BRITISH-EGYPTIAN SUDAN.

A recent importation of several varieties from the region of Khartum shows that the leading varieties are of the durra type found in Lower Egypt, some of the varieties being identical. The seeds average smaller, but this may be due to the less luxuriant growth of the Sudanese plants. Besides the usual forms with white, pale-yellow, and pale-brown seeds, there is one with gray seeds. This last variety has proved quite early and a fair yielder, and may ultimately become a profitable crop in the United States. The seeds tend to become white under our climatic conditions. The other varieties are now being grown for the first time, and their maturity will be watched with interest in the hope of finding some of value.

ABYSSINIA.

The sorghums of Abyssinia are yet but little known. In a considerable collection of the seeds sent from that country to France in 1840 it is reported that a large number of varieties was found. Some of them were full of very sweet juice, some but slightly sweet, and others not at all so. Their other varietal characteristics were not indicated. Very meager data have accompanied the few shipments of seed received in this country from Abyssinia. Most of the varieties are apparently very late, and only occasionally can one be brought to the flowering stage, and none to maturity, in the United States. Most of them are very tall and stout (fig. 5) and of apparent kinship with the larger varieties of India. Some are shorter and freely stooling, though with stems of enormous size. The mixed seed in one lot are apparently identical with those of the yellow and brown durras (safra and ahmar) of Egypt. Many of the sorts introduced have apparently been badly hybridized. None of them give promise of being of any value, unless for silage and fodder on the Gulf coast. Since the interior of Abyssinia is a high and dry plateau, it may be that varieties suitable for our high plains will yet be discovered there.

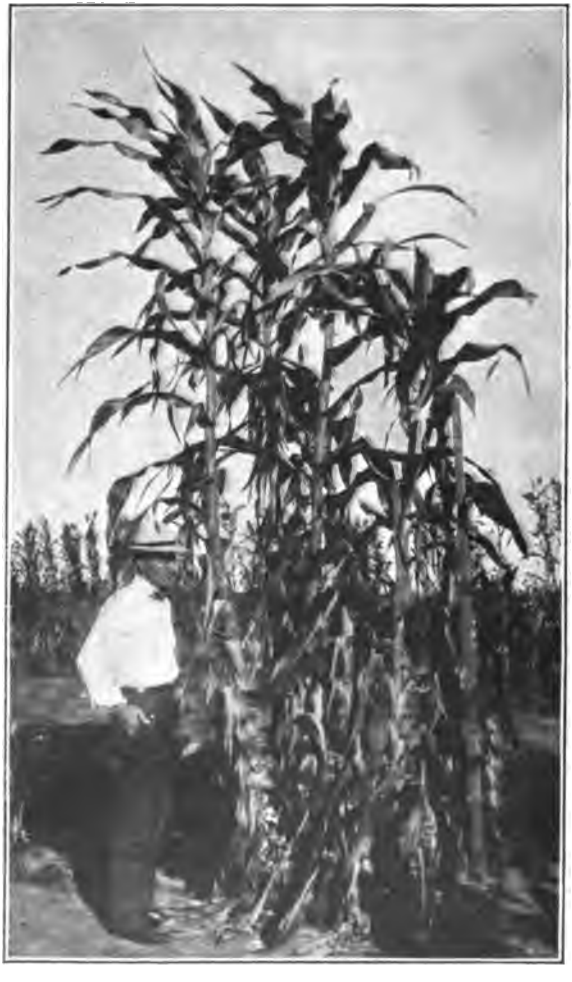
FIG. 5.—Plants of an Abyssinian sorghum not yet headed.

NORTH AFRICA.

Northern Africa may be separated into two regions, in each of which sorghums are grown to a considerable extent for human food.

These regions are (1) Egypt and (2) the Barbary States. The varieties found in each are different, and also differ from those of equatorial Africa.

EGYPT.

In Egypt, durra is used as a general term to designate all succulent forage. All sorghums are called durra beladi to distinguish them from corn, durra shami. The fall-sown sorghum is called nili and the spring-sown, or common crop, sefi. The varieties with erect heads are called aym, those with pendent heads awagi. There are three sorghum varieties in common cultivation, all belonging to the spring-sown crop with erect heads, or the durra beladi sefi aym. The three are known as beda, or white seeded; safra, or yellow seeded; and ahmar, or brown seeded. Beda is grown more extensively than all the others combined. Where grown in this country all three are very tall and very stout forms of the durra group, 10 to 14 or more feet in height, with 20 to 30 leaves on each stalk. All possess larger seeds and more closely compact heads than are found in any other varieties of the durra group. They are of no apparent value for any part of the United States.

It is possible that safra, the yellow-seeded variety, was the foundation stock for the milo of this country. They are very much alike in both glume and seed characters, including the awns. These Egyptian forms, while larger in the size of plant and seed, are rather similar to some forms from Abyssinia and from India. The probable relationships of these sorts are more fully discussed under the heading "Botanical history." The groups of sorghum so common in central and southeastern Africa are not found in Egypt, with the exception of an occasional kafir in Upper Egypt, an evident stranger from the South.

BARBARY STATES.

In Morocco, Algeria, Tunis, and Tripoli, comprising the Barbary States, the leading variety of sorghum is a white durra (fig. 6, *b*), called bechna, or beshna, by the Kabyles of Algeria. It is practically identical with that introduced into this country as Egyptian corn, known later as rice corn, and more recently as Jerusalem corn. It is probably not indigenous to North Africa. A very similar white durra is found throughout Turkestan, Mesopotamia, Syria, and Arabia, and the North African plant is probably a result of the Arab invasion of that region in the third century. There is also found sparingly among the mountain tribes, or Kabyles, of Algeria and in certain oases in the northern Sahara a red-seeded durra very similar to our brown durra and very likely the original form of it. This form has not yet been found in Arabia or elsewhere in southwestern

Asia. The physical and climatic features of the two regions are quite similar, and the almost complete absence of any other forms has prevented much hybridization. For that reason there has apparently been but little change in the varieties in many centuries.

The climate of much of this North African region is dry and hot. The white durra when grown in our Western States is very early and drought resistant and likewise a fair yielder. Its chief faults are the pendent heads of most strains and the freely shattering seeds. The shattering habit does not seem to yield to continued selection. If a strictly nonshattering strain could be found in North Africa, it would be of great value for our higher altitudes and latitudes. The brown durra is an inferior sort and gives little promise, though it is also early and able to grow with little moisture.

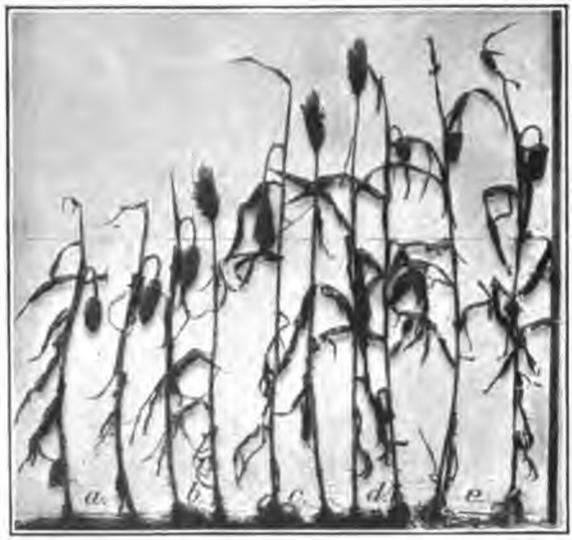

Fig. 6.—Plants of white durra from different countries, showing varying characters. The stalks in pairs, from left to right, are from (*a*) the United States, (*b*) Algeria, (*c*) Austria, (*d*) Turkestan, and (*e*) Syria, respectively.

SOUTHWEST ASIA.

White durra, the single variety found throughout the region of Asia Minor, Russian Turkestan, Syria, and Arabia (see fig. 6), has already been mentioned. In the southern part of this area it has certainly been grown for nine centuries, and probably for three times that period. The form commonly grown in these lands differs from that of North Africa and the United States in having the heads shorter and more compact and the seeds smaller, less flattened, and with less tendency to shatter. The heads of nearly all strains are persistently pendent or goose necked. In parts of this region the white durra grows under exceedingly high summer temperatures. It is possible that very drought-resistant strains may be secured here. However, those brought from this region heretofore have not seemed to be more especially drought resistant than our best developed strains of kafir and milo. A nonshattering form of white durra from a dry, hot region would be of great value on our dry and windy plains.

The land tax levied by the Turkish Government is paid by the natives in the seed of this white durra. The people are required by the officials to present in such payments cleaned and selected seed, much better than the average found on the market or used in their homes for food. No other sorghums are found in all this great region except occasionally a little Amber sorgo introduced from Europe or America.

INDIA.

In the number of varieties of sorghum and the relative importance of the crop, India ranks second only to tropical Africa. The total area grown in India and Burma is now about 25,000,000 acres annually. Though cultivated for many centuries and forming a staple and very important article of human food and of export, Indian varieties have apparently not been selected or improved for grain production. The average grain yield obtained there would be considered very small in this country. According to the best statistics obtainable by the British Government and published recently, 10 bushels to the acre would seem to be a fair average for the grain yield of sorghum in India. Methods of cultivation are crude, and losses by drought, fungi, insects, and birds are considerable. It does not appear that the soil is especially poor, in spite of centuries of cultivation. This may be largely due to an abundant use of legumes, both as staple crops and as fillers or subordinate crops.

As noted, the number of varieties is very large. They vary in the different native states, and the names applied to them are much more numerous and variable than the forms themselves. Many of the varieties would be classed as durras, though none is identical with any of our cultivated durras. In color the seed of most of them is white or pearly yellowish, but in a few it is red. The heads, and the seeds as well, average quite small, though the plants themselves are usually both tall and stout (fig. 7). This is probably explained by the fact that in India the plants are always grown for both fodder and human food. Owing to their large size they are inclined to be rather late in maturing. A few varieties are dwarf in height, but these also have stout stems and mature with us scarcely earlier than the others. Rather compact heads and firm glumes are characteristic. One or two very large varieties are two seeded; that is, they have two fertile flowers and produce two seeds in each spikelet, instead of one, as is normal for the sorghums.

From more than 300 different lots of Indian origin, which have been studied by the writer, only one or two have seemed worthy of attempts at improvement. The small size and hard nature of the seeds would necessitate grinding to make them profitably available as stock food. To eliminate the large size of the stalk and bring the grain yield up to a profitable quantity would require several years of careful selection. There is nothing in the appearance of the varieties to indicate that at the end of this period one might hope for anything better than, or even equal to, the best kafirs, white durra, and milo which we now possess. It should be possible to secure some excellent early and drought-resistant varieties in India by searching through the middle and northern parts of the Empire, as Berar, the Central Provinces, the United Provinces of Agra and Oudh, north to the Punjab and the frontier. Those previously introduced have come from the Madras and Bombay Presidencies.

Besides the durra-like forms, there are a few minor groups, of which only one needs special mention here. In all the writings on Indian agriculture concerning the sorghum crop there are references to a fall-sown, or rabi, crop. The great bulk of sorghums in India, as elsewhere, is sown in the spring and harvested in the summer or autumn. The rabi crop, on the contrary, is sown in September or October and harvested in the following February or March. From all available information this rabi crop is mostly composed of a single variety or group of very similar varieties, which is commonly called "shallu," or "shalu." Botanically these forms represent the variety *roxburghii* Hackel. The rabi crop is most largely grown in the Bombay Presidency, although not unknown in other sections of India. The shallus are characterized by rather slender stems, large, loose, and open panicles, and oval yellowish or straw-colored spikelets. The two indurated (empty) glumes spread wide apart at maturity and each becomes involute, thus leaving the white or pearly seed fully exposed. One variety of this group has been sparingly cultivated in our lower Plains region for several years and is now being carefully tested as a grain sorghum. (See fig. 4.)

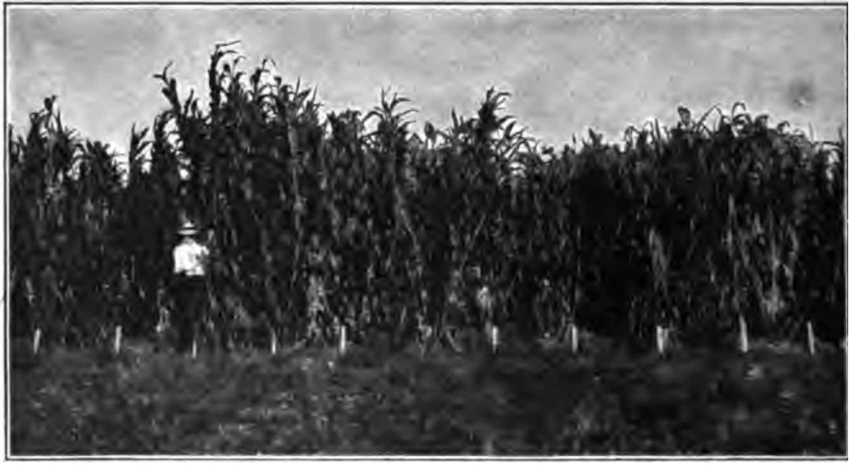
FIG. 7.—Plants of different varieties of sorghum from India.

A saccharine, or sirup-bearing, variety of sorghum is said[a] to have been largely grown locally for a long time at Bikanir, a point in northwest India, but seed of it has not yet been secured. A few saccharine varieties were introduced from this country into India thirty or more years ago, but did not prove popular in a country where the same variety is expected to supply both human food and animal forage. Amber and Collier sorgos, more or less pure, are still found there locally in very limited quantities.

The large varieties of Abyssinia seem to be very similar to, if not identical with, some of the larger India varieties, so far as one may judge from immature specimens of Abyssinian plants. Commercial intercourse between India on the one hand and Egypt and Abyssinia on the other has always been very free, and it would be surprising indeed if there had not been an interchange of the commonly cultivated crops. This may explain the similarity of some forms in the two regions.

There is abundant and quite conclusive evidence that cultivated sorghums have originated independently in India and in Africa. *Andropogon halepensis*, the presumable parent form, is abundantly distributed and highly variable in India. In some sections it is sparingly cultivated. In times of famine the seeds of this wild species are generally utilized for food. It has been suggested by agricultural writers of India that some of the forms now cultivated have been so recently and directly derived from *Andropogon halepensis* that they may still be referred to it rather than to *Andropogon sorghum.*

CHINA.

In China sorghum is called " kowliang " (fig. 8), or " tall millet," to distinguish it from the various smaller millets, species of Panicum and Chaetochloa (Setaria). All the forms studied by the writer, except the single saccharine variety, belong to a single related group of sorghums, which will henceforth be called the " kowliang group." Three varieties used as food have been distinguished: Brown kowliang, the most common one, with brown seeds and black glumes; blackhull kowliang, with white seeds and black glumes; and white kowliang, with white seeds and pale or greenish glumes. The stems are slender, usually quite dry and pithy, 4 to 11 feet in height, with oblong, somewhat open panicles 6 to 12 inches in length. Most of the strains secured have very tall stems, due apparently to the need of the Chinese to obtain as much fodder and fuel as possible with the grain. While none of the introduced strains are heavy yielders of grain, some of the dwarf forms are extra early and promise to be valuable as grain crops on our high plains if their productiveness can be sufficiently increased. A brown-seeded form with the panicle branches elongated is used for brooms and brushes.

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[a] Watt, 1893, p. 283; 1906, p. 111.

This group is apparently confined to the northeastern part of China proper and to adjacent Manchuria, from latitude 38° to 41° north. In this region it is very important. The seed is used for human food, the stems and leaves for fodder, thatching, fences, and baskets, and the stems and roots for fuel. Since *Andropogon halepensis* is not native in this portion of China, there is little probability of a Chinese origin for the kowliangs. They are not like any varieties so far found in India or in any other country. These facts seem to point to their introduction into China many centuries ago and their subsequent modification to the present forms. Since authentic references to a sorghum are found in Chinese literature at least as early as the third century A. D., this theory seems the most probable one.

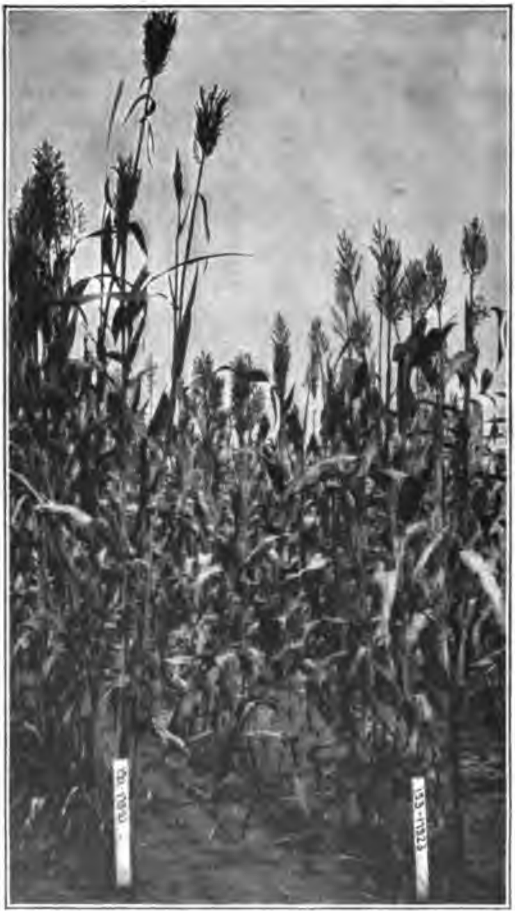

FIG. 8.—Plants of two varieties of kowliang from China.

In 1851 the seed of a variety of sorgo or saccharine sorghum was sent to France from the island of Tsungming (Chungming) in the mouth of the Yangtze River, latitude 32° north. From the brief and unsatisfactory descriptions and illustrations (fig. 9) of it published in France and in this country, we know that it had a tall and slender stalk, with about thirteen leaves, and a loose, conical panicle, with more or less drooping branches, and light-brown seeds completely enveloped in shining black glumes. These characters show that it was very similar to some of our forms of Amber sorgo. Our Early Amber is said to have originated in 1859 as a sport in a field of Chinese sorgo growing in Indiana.

No other saccharine variety has been found in China. This one is said by Collins[a] to be almost entirely restricted to the island of Tsungming, where it is cultivated as a delicacy for the Shanghai market, the sweet stems being eaten raw. The annual area sown on the island is only about 20 acres. Since the original importation in 1851 no seed, except that sent by Collins, was ever brought to the United States until May, 1908, when a few seeds (S. P. I. No. 22913), secured on the island of Tsungming, were received by the Office of Seed and Plant Introduction of this Department. These seeds were of poor quality and the resulting plants did not fully mature, but are apparently identical with some forms of Amber now grown in this country. There is, however, little doubt of the independent African origin of some Amber forms.

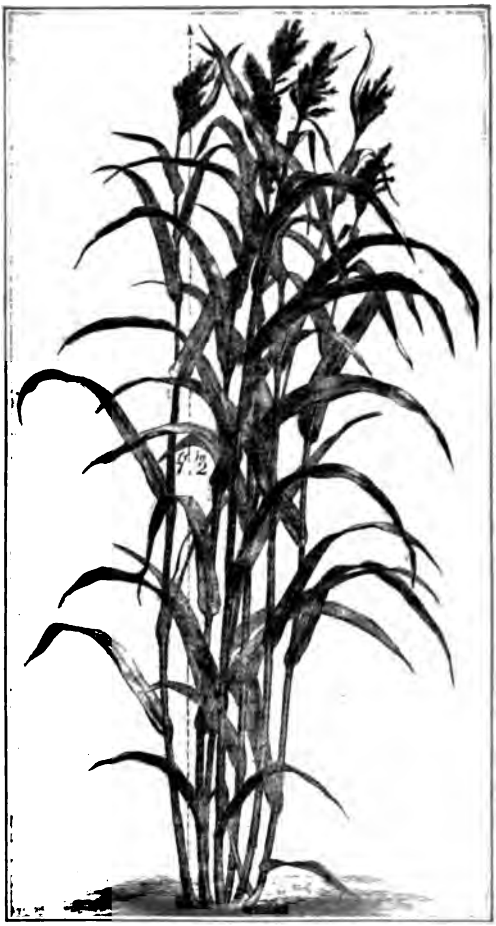

FIG. 9.—Plant of Chinese sorgo. (From Patent Office Report, 1854.)

That form of kowliang which somewhat resembles broom corn is found also in Korea and Japan. It would be classed as very poor brush in the United States. Some improved broom corn is grown in Japan, but it is probably from seed originally secured in Australia, Europe, or the United States.

PACIFIC ISLANDS.

The tropical islands of the Pacific show very few sorghums or none at all. Some of the larger islands, like Java, lying near the continent of Asia, have one or two varieties, apparently of Indian or American derivation. In Australia the standard varieties are all importations from the United States. Numerous native varieties from India and the British colonies in Africa have been tested in Australia recently and a few are likely to persist in cultivation, at least for some years.

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[a] Collins, 1865, p. 91.

EUROPE.

Pliny (70 A. D.) records that a variety of sorghum was introduced from India into Italy about ten years previously. Its cultivation in Italy has apparently been continuous since the earliest introduction, and it was there that the name surgo, or sorgo, was first applied to the crop. In the extensive commerce of Greece and Rome with Africa and Asia it is probable that other importations of sorghum reached the northern shore of the Mediterranean Sea from time to time. By the end of the fifteenth century the cultivation of one or more forms of sorghum had become quite general in all of southern Europe from Greece to Portugal. It had also gradually extended northward to Germany (fig. 10), France, Belgium, Holland, and even to England. In these more northern countries it was probably grown as a curiosity in botanic gardens and did not always mature. It was generally known as Indian millet or reed millet to distinguish it from the smaller millets.

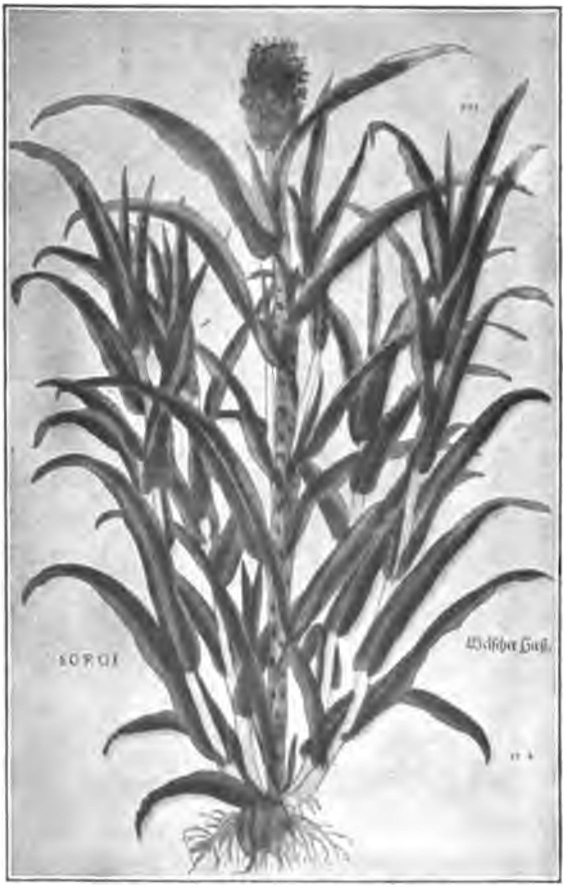

FIG. 10.—Plant of sorghum, after Fuchs, 1542.

In southern Europe the seed at that time had come into common use for fattening pigeons and poultry and less commonly other stock. The forage, both green and cured, was used for various kinds of cattle, though it was early noted that animals sometimes died after grazing on the living plants. The seed was also commonly used in the making of bread by the poorer, or peasant, classes. This bread was brittle, dark colored, and more or less astringent. It was generally regarded as inferior in nutritive qualities to that made from the other millets, as *Panicum miliaceum* and *Chaetochloa* (*Setaria*) *italica*, or that from the larger cereals. The flour was also commonly made into a porridge with milk. The semisweet pith and sometimes the flowers were used in medicine.

The development of a broom corn from some loose-panicled sorghum took place in Italy more than two hundred and fifty years ago. Caspar Bauhin in 1658 states that the slender and very rigid dried heads were made into brooms by the Italians and used for brushing clothing in Italy, France, and also Germany. Ray in 1688 gives a full discussion of sorghum and records this use of the plant, stating that he himself had seen such brooms on sale in Venice. From just what form of sorghum this selection took place can never be known, but in figure 11 a loose-panicled form is shown, first pictured by L'Obel in 1576 and copied by Dodoens. Arduino in 1786 figures one more spreading than our Amber sorghum (fig. 12) and another with the rhachis much shortened (fig. 13), either of which would have been an excellent basis for broom-corn selection.

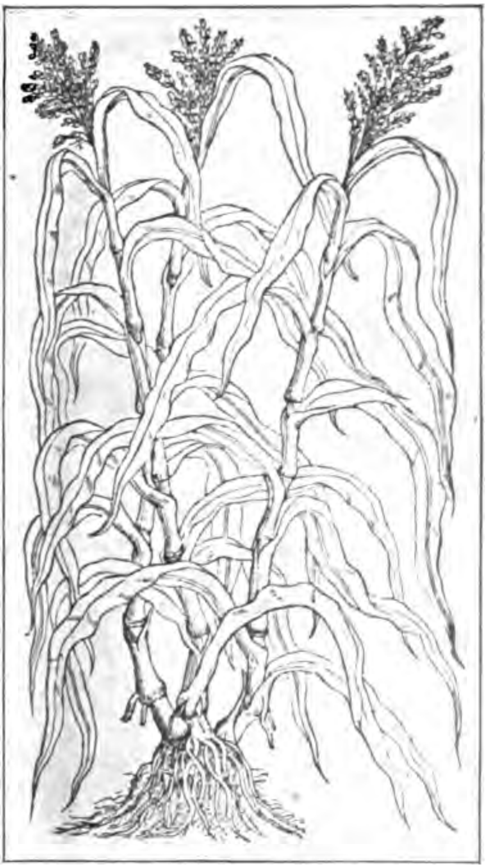

FIG. 11.—Plant of sorghum, after Dodoens, 1583.

The form introduced into Europe during Pliny's time seems to have been on the order of the sweet sorghums, even though it is not known to have had a sweet juice. It is noted as having stout culms, 7 feet high, and abundant black seeds, the color doubtless referring to the inclosing glumes. Most sixteenth to eighteenth century writers who mention these details describe this sorghum as having reddish seeds and black glumes, with culms from 7 to 10 feet or more in height and heads about 9 inches long. Many writers from the tenth to the eighteenth century describe also the white-seeded sorghum used by the inhabitants of Asia Minor, Arabia, and Mesopotamia, but none records its introduction into Europe. All references to its growth in Cicilia, or Sicilia (Sicily), are misprints for Cilicia. This form has been discussed under the heading "Southwest Asia."

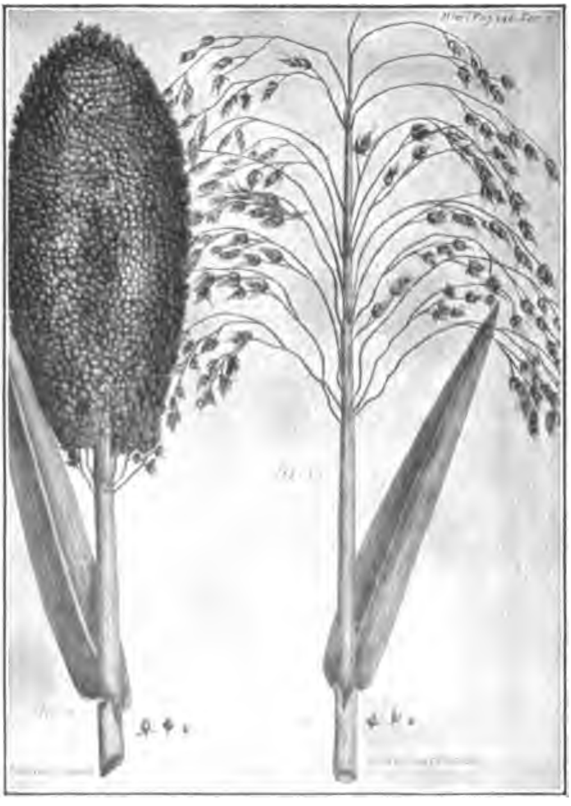
FIG. 12.—Heads of Holcus sorghum, L., and Holcus saccharatus, L., after Arduino, 1786.

About 1775 Arduino began at Padua, Italy, his experiments in sugar production from sorghums. He carried on this work for fully ten years, and in 1786 published a comprehensive paper in which he described six supposed botanical species of sorghum and gave full notes on their culture and uses. He seems to have been the first author who gathered together and grew for a number of years all the forms he could secure. Of the six varieties thus described as species, one was a new sweet sorghum from "Cafreria" (Natal), South Africa, one was the white durra of southwestern Asia, and the other four were forms long cultivated in Italy. The six species were all splendidly illustrated on folio plates, which are here reproduced as figures 12 to 15. They were all commonly used for human and animal food, and the older ones were also used in the making of brooms. After Arduino's work ceased, for causes not explained, no especial attention seems to have been given to sorghum for sirup or sugar production until the middle of the eighteenth century.

In 1851 a saccharine sorghum from China arrived in France. It had been sent with many other seeds to the Royal Geographical Society by M. Montigny, the consul at Shanghai. It was obtained from the island of Tsungming (Chungming), lying in the mouth of the the Yangtze River, in latitude 32° north. A single seed is said to have germinated in the garden at Toulon, where the seed was sent. The resulting crop was secured at a high price by Louis Vilmorin, of Vilmorin-Andrieux & Co., well-known seedsmen of Paris. This seed, sold widely in Europe and afterwards in the United States, was the foundation of the variety long known as Chinese sorgo (fig. 9).

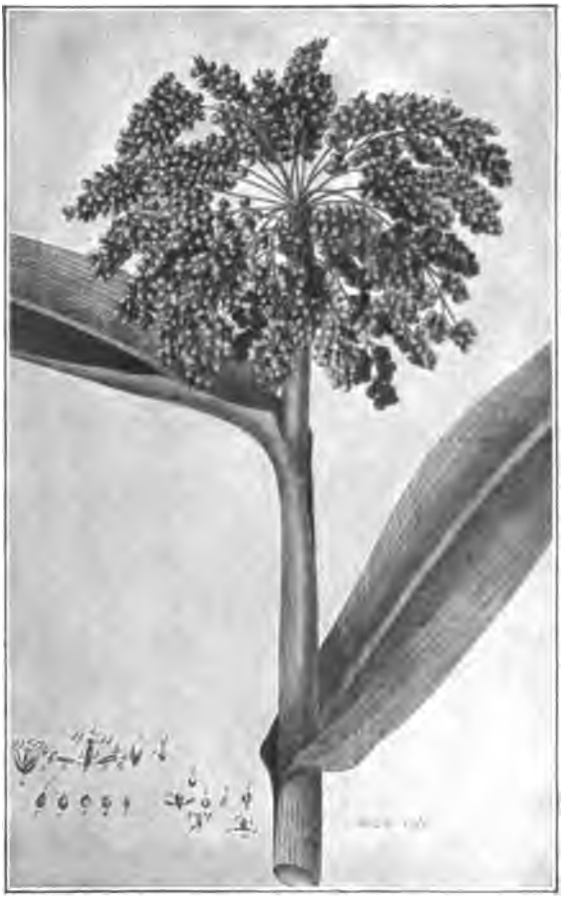

FIG. 13.—Head of Holcus cafer, after Arduino, 1786.

In March, 1851, Mr. Leonard Wray, an English sugar planter, arrived in Natal, South Africa. Soon after, his attention was attracted to numerous varieties of sorgo called "imphee," which the Zulus or Kafirs cultivated for the sweet stems. These people knew nothing of the art of expressing the juice by mechanical means, but simply chewed the peeled stems. After considerable search Mr. Wray succeeded in getting together sixteen varieties under their native names. These he brought to Europe about 1854 and arranged to have grown in various countries. From these varieties have descended most of the sorgos now grown in the United States.

With these two importations was inaugurated a long series of thorough and expensive experiments in making sugar and alcohol from sorghum, which continued without interruption for thirty years. During the progress of similar work in America, large quantities of the seed of our leading saccharine varieties were sent from here to Spain and other parts of southern Europe. Neither these nor Mr. Wray's original importations seem to have persisted there in cultivation as pure varieties.

At the present time few varieties are to be found in Europe, and these are usually very badly mixed. A rather large, somewhat saccharine variety, with spikelets much as in Gooseneck sorgo, but with a compact, obovate, erect, black head, is found in Germany, France, and Austria. It is quite different from any variety now grown in the United States and is probably a remnant of the importation from Natal. Some Amber and Orange sorghum can still be found in France and Spain. It is probable that the blood of a number of the different saccharine varieties is mingled in the variable and often worthless hybrids now found in southern Europe.

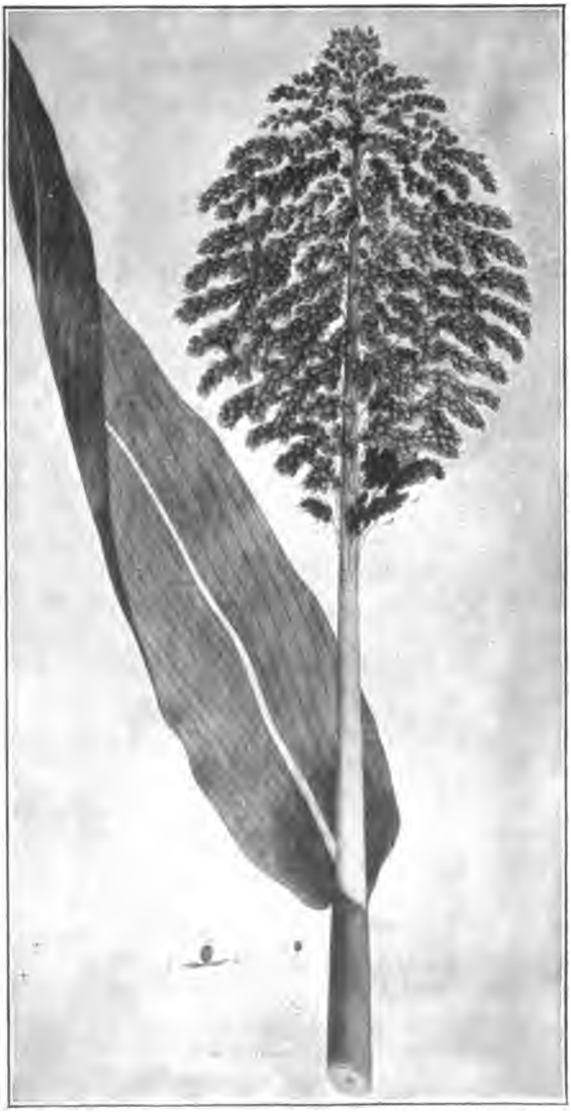

FIG. 14.—Head of Holcus niger, after Arduino, 1786.

A white durra is found in occasional cultivation in Europe. It is the form prevalent in northern Africa rather than that of Arabia and Syria, and has come largely from Algeria by way of France (fig. 6, *c*).

SOUTH AMERICA.

No sorghum varieties are indigenous to the New World. *Andropogon halepensis* itself is an introduction, though now found abundantly in tropical and subtropical America. In South America broom corn is quite widely but not extensively grown. Amber sorghum from the United States is sparingly introduced. No other varieties are found, except occasionally under trial at experiment stations.

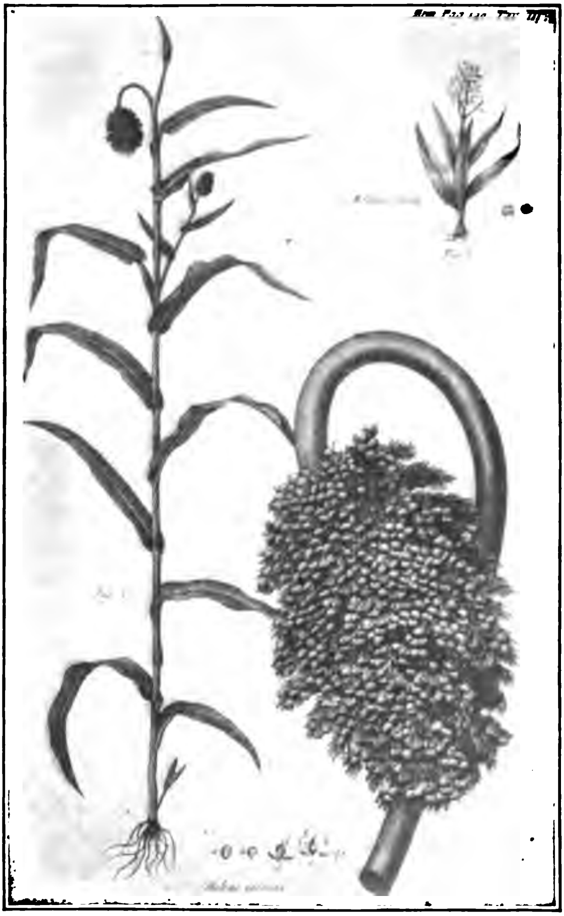

FIG. 15.—Plant and head of Holcus cernuus, after Arduino, 1786.

WEST INDIES AND CENTRAL AMERICA.

Throughout the West Indies and sparingly on the east coast of Central America a variety is found quite similar to blackhull kafir in the characters of the head. In its vigorous stooling and abundant leaves it still more closely resembles other African varieties. It was introduced long ago from the Guinea coast of Africa with the slaves, whose food it had been in their native home. Sloane records it as widely cultivated in Jamaica in 1707. In the English islands it was, and still is, known as "Guinea corn," in the French islands as "petit millet," and in Honduras as "maysillo" (probably "little corn"). It is quite generally cultivated for human food for the laboring classes, and also as forage for stock. The small seeds are white or pearly white in color and the short glumes are usually black. It is probably the progenitor of the form occasionally found in the United States under the name "white millo maize," and for which the author has suggested the name Guinea kafir. It has no value in this country, unless perhaps for silage in the extreme South.

UNITED STATES.

The early history of sorghum varieties in the United States is quite obscure. It is known that the growing of broom corn for domestic use became a considerable industry in colonial times. It is certain also that some grain varieties were introduced and sparingly grown in the early days of the colonies. From time to time a variety, though not always the same one, was exploited, under the name of "chocolate corn," as a substitute for tea and coffee. However, aside from broom corn, no sorghum had become a permanent crop before the middle of the last century.

Accounts vary somewhat as to the date and manner of the first introduction of the Chinese sorgo (fig. 9) from France. Apparently it was first grown by William R. Prince,[a] a nurseryman, of Flushing, Long Island, New York, in 1853, and sold by him to a few other persons for testing in 1854. A hogshead of seed was sold by him in 1855. The United States Commissioner of Patents[b] secured a small quantity of the seed in France in 1854 and grew it in 1855, continuing the experiment through the succeeding year. In that year, 1856, a 75-foot row was grown by the editor of the American Agriculturist[c] from seed secured from the firm of Vilmorin-Andrieux & Co., of France. In the spring of 1857 the American Agriculturist distributed over 1,600 pounds of the seed to 31,000 of its subscribers. Most of the seed was imported direct from France, though a small quantity was secured from growers in the vicinity of New York, N. Y. In the same year the United States Patent Office distributed 175 bushels of home-grown seed and 100 bushels of imported seed. In the spring of 1858 the American Agriculturist distributed, in 1-pound packages, 34,500 pounds of seed grown in Georgia from its imported seed of the year before. It is not probable that extensive distributions were made after this date. The supply already sent out was sufficient to scatter the variety very extensively over the entire country. The widespread and increasing interest in this crop was not because of its forage, or even its sirup value, but as a probable source of sugar. It was then known as sorgho in Europe and America.

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[a] Report, U. S. Dept. of Agriculture, 1877, p. 233.

[b] Reports, U. S. Patent Office, 1854, pp. xxii and 219–223; 1855, p. xii and 279–280; 1856, p. 5. Report, Iowa State Agricultural Society, 1861, p. 207.

[c] American Agriculturist, vol. 20, 1861, p. 6; vol. 39, March, 1880, p. 116; vol. 40, March, 1881, p. 94.

In May, 1857,[a] the sixteen saccharine varieties obtained by Mr. Leonard Wray in Natal in 1851 were brought by him from Europe to the United States at the request of Hon. Horace Greeley. They were not distributed to the public, but were first sown in South Carolina and Georgia under Mr. Wray's immediate supervision. He had taken out United States patents on his method of making sirup and sugar, and is said to have purposed controlling the income from the use of his varieties. These African varieties were known collectively as "imphee," each variety having in addition a native Zulu name. The names of the varieties, as published by Olcott (1857), were as follows: Vimbischuapa, Eanamoodee, E-engha, Neeazana, Boomrwana, Oomseeana, Shlagoova, Shlagoondee, and Zimmoomana, with brief descriptions, and Ebothla, Booeeana, Koombana, See-engla, Zimbazana, and Ethlosa, mentioned by name only. In the pronunciation of these names each vowel, except where doubled, is the basis of a syllable. Though only fifteen names appear, Mr. Wray states that sixteen varieties were obtained by him in Natal. Many years later Wray[b] identified plate 5 in Special Report No. 33 of the Department of Agriculture and in the report of this Department for 1880 as his "Enyama," which is not given in the list above, but was doubtless the sixteenth variety. A variety was on sale in the city of New York under this name in the spring of 1859.

Between the years 1860 and 1880 agents were sent to China[c] to discover and bring back other varieties, and considerable importations were made also from South Africa and India.[c] No other saccharine varieties were found in China, though several ordinary kowliangs were obtained. The importations from Africa, though coming under names very different from those of Mr. Wray's forms, apparently did not represent any new varieties. The Indian varieties were either nonsaccharine or so slightly saccharine as to be valueless for sirup or sugar production. They were mostly too late to be of much value for forage and grain.

All these varieties were soon as widely distributed over the country as their particular climatic adaptations would permit. Hybridization, variation, and selection, combined with the desire of growers to find a market for their seed, resulted in the speedy multiplication of the so-called "varieties" to an enormous extent. Two hundred or more names are recorded for saccharine varieties alone. It is doubtful if the number of actual varieties concerned was ever more than twenty. Not more than a dozen are now in cultivation in this country. Of these, Amber and its forms are said to be directly derived from the original Chinese sorgo, though it has not been proved that some of these forms were not secured in Africa. All others are presumably descended from the Natal varieties. The definite varietal origin of some is known, as Orange and perhaps Planter from Neeazana, and Sumac from Koombana; others, as Collier, Planter, Sapling, Gooseneck, Honey, etc., can not be certainly connected with a particular one of the poorly described African varieties, but are most surely original sorts from that source.

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[a] Hedges, I. A. Rural New Yorker, vol. 40, May 7, 1881, p. 1. American Agriculturist, vol. 16, 1857, pp. 142, 276–277.

[b] See Collier, 1884, p. 68.

[c] Sorgo Journal, vol. 7, October, 1869, p. 91; Collier, 1884, loc. cit., pp. 76–82; American Agriculturist, vol. 45, April, 1886, pp. 153–154; Bulletin 20, Bureau of Chemistry, U. S. Dept. of Agriculture, 1889, pp. 112, 119.

The sorgos, or saccharine sorghums, are now grown to a very limited extent for sirup production and to quite a large extent for forage. The total area grown in the United States is probably about one and one-half millions of acres annually. A large part of this is in the southern half of the Great Plains area. During the recent unusually wet seasons there has been a perceptible decrease in the acreage in that region, owing to the opportunity for better crops of corn and cereals. The Amber, Orange, and Sumac varieties make up the bulk of the crop.

Kafir and durra are of quite recent introduction and distribution in the United States. Varieties of the kafir group first reached this country in 1876, but were not generally distributed until ten years or more later. The original variety, white kafir, has almost completely disappeared from cultivation. Its place has been taken by the more recent blackhull kafir, which makes up probably nine-tenths of the total kafir crop, red kafir furnishing the remaining tenth. White durra and probably other durras have been introduced many times since colonial days, but without permanent results until 1874, when our white durra and brown durra were brought into California. The total area of these two crops probably does not exceed 50,000 to 60,000 acres annually. Milo appeared about 1885 under circumstances not yet ascertained. The annual acreage is probably about 300,000 acres. The total area devoted to kafirs and durras combined is probably not far from another one and one-half millions of acres. This would make a grand total of three million acres of sorghums annually grown in the United States.[a] Their annual value may be conservatively estimated at $30,000,000.

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[a] These estimates were made in June, 1908.

CANADA.

The earliest maturing varieties of sorgo from the United States, chiefly Amber and its forms, have been grown in Lower Canada for some years as hay and fodder crops.

BOTANICAL HISTORY AND NOMENCLATURE OF SORGHUM.

PRE-LINNEAN PERIOD, FIRST CENTURY TO THE YEAR 1753.

During the early part of the pre-Linnean period sorghum was introduced into Europe and became widely cultivated under many popular names. With the revival of learning in the latter part of the period it received abundant attention in agricultural and medico-botanical literature and acquired a considerable polynomial nomenclature.

According to Pliny, as has been stated, sorghum was introduced into Italy from India during the first century. In his writings he includes it under the general term "milium," or millet, used then, as now, to designate the cultivated forms of several different species of grain-producing grasses. The most important of these were the grasses now known as *Panicum miliaceum* (proso millet) and *Chaetochloa* (*Setaria*) *italica* (foxtail millet). Pearl millet (*Pennisetum spicatum*) and even corn (*Zea mays*) were included under the name milium by various ancient authors.

Even from the very brief description given by Pliny we may be sure that he was writing of some sorghum. "Milium intra hos decem annos ex India in Italiam invectum est, nigrum colore, amplum grano, harundineum culmo, adolescit ad pedes altitudine septem prægrandibus culmis: lobas vocant: omnium frugum fertilissimum. Ex uno grano terni sextarii gignuntur. Seri debet in humidis. Frumenta quædam in tertio geniculo spicam incipiunt concipere, quædam in quarto, sed etiam num occultam." The very stout, reed-like culms, 7 feet tall, exclude all other millets except pearl millet. The abundant grain and black color separate it from that species, while all these characters agree readily with those of sorghum.

ORIGIN OF POPULAR NAMES.

The name milium is derived from miliarius, or milliarius, which means "containing a thousand," and has reference to the large number of seeds in each head. From it our words millet, millo, and milo have been derived. For many centuries sorghum in general was known as milium, or milium indicum, literally Indian millet, and this latter name was still in use fifty years ago. Just how early other names came into use for sorghum can never be known, owing to the lack of literature on such subjects during mediæval times. It is natural that such names should have originated soon after the introduction of this crop and should have increased in number as the plant became more widely distributed among tribes and nations.

By the beginning of the sixteenth century sorghum was to be found throughout Italy, Spain, France, Belgium, and Germany under a great variety of names. A very large number of these names were used in different parts of Italy. Melica, melega, and milica were derived from either "mel" or "mellis" (honey), or more probably from "melligo" (a honey-like juice). Sagina, or saggina, was derived from the Latin "sagino," to fatten. Sorghi, sorgi, sorgho, sorgo, sorghum, and surga are derivatives from the Latin "surgo," to rise or tower, in reference to its towering high above all other crops. In Germany there was applied to it the distinctive name "Welschenhirse," i. e., foreign, or, more particularly, Italian millet, and also "Sorgsamen." In Belgium the name "sorgsaet" was given it. The derivation of these last names from the Italian "sorgho" is obvious. It was known also as *Milium indicum*, *M. insubrum*, *M. sabaeum*, and *M. saracenicum*, as the seed was thought by the various writers to be of Indian, North Italian, Arabian, or Saracenian origin, respectively.

Throughout the past century all writers on sorghum in cyclopedias and agricultural and botanical works have reiterated that the name sorghum, or sorghi, is the common name of this plant in the Orient. There is not the slightest evidence in support of the theory; on the contrary, as early as 1592 Porta had pointed out its origin from the Latin "surgo."

Early Authors and Early Names.

It is impossible to take up in detail the statements made by the many medical and agricultural writers of the sixteenth century and earlier. The latter repeated the facts and also the errors of the earlier authors, with additional notes of their own. The following is a chronological list of the more important pre-Linnean authors, showing the names under which they discuss sorghum. In most cases they also cite other names by which sorghum was known among the different nations of their time:

Pliny, first century, "Milium ex India."
Ruel, 1537, "Mellica."
Crescenzi, 1542, "Saggina," "Melica."
Fuchs, 1542, "Sorgho."
Tragus (Bock), 1552, "Panicum."
Scaliger, 1556, "Sorghum."
L'Obel, 1576, "Sorgho," "Melica Italorum."
Dodoens, 1583, "Melica" or "sorghum."
Cæsalpini, 1583," "Melica," "Sagina."
Porta, 1592, "Sagina," "Melica," or "Surgo."
Mattioli, 1598, "Milium Indicum."
Belon, 1605, "Sorghum Insubrum."

Besler, 1613. "Milium Plinii;" "Sorghum fructo rubro;" "Sorghum fructo albo."
Bauhin, C., 1623, "Milium Sabaeum;" "Milium arundinaceum subrotundo semine, Sorgo nominatum;" "Milium arundinaceum plano alboque semine."
Parkinson, 1640, "Melica, sive sorghum."
Bauhin, C., 1658. "Milium arundinaceum sive Indicum semine subrotundo;" "Milium arundinaceum semine plano et albo."
Hermann, 1687, "Milium indicum, arundinaceo cauli, granis flavescentibus;" "Milium indicum, arundinaceo cauli, granis nigris;" "Milium arundinaceum subrotundo semine; Sorgo nominatum;" "Milium arundinaceum plano alboque semine."
Ray, 1688, "Sorghum" or "Milium Indicum;" "Milium arundinaceum semine subrotundo;" "Milium arundinaceum semine plano et albo."
Breyne, 1689, "Milium Indicum sacchariferum altissimum semine rotundo atro;" "Milium Indicum sacchariferum altissimum semine ferrugineo."
Sloane, 1696, "Milium Indicum."
Morison, 1699, "Milium majus Sabaeum;" "Milium majus arundinaceum subrotundo semine;" "Milium majus arundinaceum plano alboque."
Tournefort, 1700, "Milium arundinaceum."
Sloane, 1707, "Milium Indicum."
Micheli, 1729, "Sorgum" (nomen nudum).
Linné, 1737, "Holcus glumis glabris;" "Holcus glumis villosis."

Just what variety of sorghum was introduced into Italy in Pliny's time we have no means of knowing. There is at least a strong probability, however, that it was a sweet variety. Pliny describes the seed or head as of a black color, apparently not distinguishing between the seeds and the black glumes which inclosed them. In recent times most black-glumed forms with seeds wholly inclosed have been saccharine varieties. At any rate, a sweet variety must have been introduced at an early date, because we find such names as melica and melega, referring to sweetness, in use as early as any names more distinctive than milium or panicum. Between the first and sixteenth centuries there is naturally not a very extensive literature on the subject. Avicenna, who lived in the tenth century, writes of a form used by the Arabs and called "hareoman" (said to be a misprint for hartoman). Crescenzi (1542) is said to have written about 1300 A. D., and later editions of his work refer to the plant in Italy as sagina, or melica. The writer has been able to consult no edition earlier than the one cited.

SIXTEENTH CENTURY WRITERS.

During the sixteenth century many able writers describe the plant and its uses; some give good illustrations. None of them recognizes more than a single variety.

Fuchs (1542) and Tragus (1552) figure similar plants with heavy and compact but erect heads (fig. 10). This sorghum is much like the Orange sorgo in general appearance and is apparently the variety afterwards named *Holcus sorghum* by Linné. It is certainly the plant so recognized by Arduino (1786). L'Obel (1576) figures a variety with more open panicles, like the early illustrations of the Chinese sweet sorghum. Dodoens (1583) and Parkinson (1640) use the same figure (fig. 11). Mattioli (1598) shows a different form (fig. 16), somewhat intermediate in head characters between the other two.

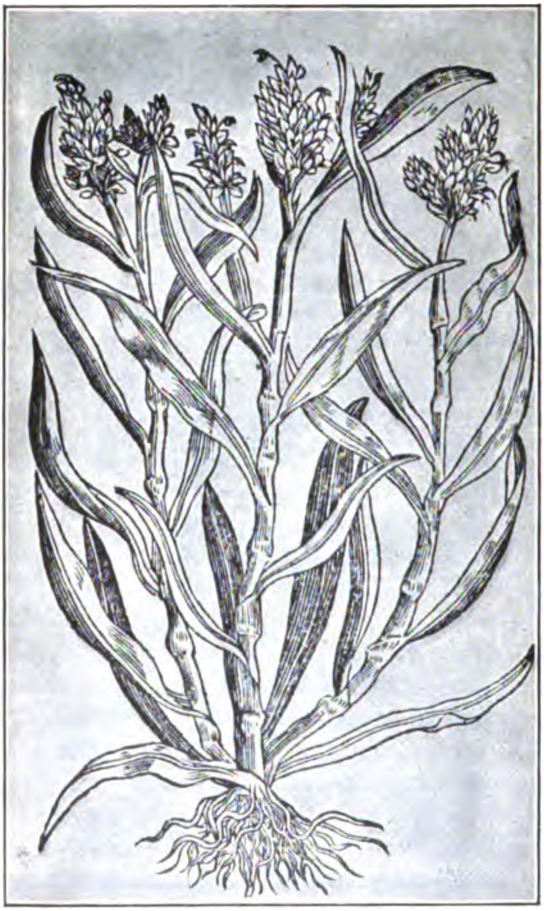

FIG. 16.—Plant of sorghum, after Mattioli, 1598.

Tragus (1552) speaks of the sweet fodder produced by sorghum. Many other writers speak of the sweet seed, but the word sweet, as used by them, seems to refer to the absence of an astringent or bitter quality rather than to the presence of any saccharine character, which would of course not appear in the seeds. None of these writers makes direct reference to a sweet juice contained in the stems or to the use of the plant as a source of saccharine matter, unless indeed the following much-quoted words of the poet Lucian, who wrote presumably in the second century A. D., "Quique bibunt tenera dulces ab arundine succos," may be construed as referring to sorghum. Except in describing the stalks as tender, this description applies equally well to sugar cane, and it may be only a bit of poetic license.

Those who describe the plant speak of the seeds as red or reddish. Some authors mention forms with seeds of various colors, from white to black. Cæsalpini (1583) states, however, that only the form with purple spikelets is the plant commonly called sagina, or melica, the others being the smaller millets.

SEVENTEENTH CENTURY WRITERS.

The writers of the seventeenth century began to separate the plant into varieties or races, based chiefly on the color of the seeds. Bauhin (1623), under the general heading "Milium Eiusque Species," names, with copious synonymy and brief description, five different kinds, the first two of which, "*Milium semine luteo vel albo*" and "*Milium semine nigro*," are probably not sorghums. The last three, however, "*Milium sabœum*," "*Milium arundinaceum subrotundo semine, Sorgo nominatum*," and "*Milium arundinaceum plano alboque semine, Sorgo simile granum, Hareomen Arabum*, Bellonio," are almost certainly different varieties of sorghum. The first of these three is not described, but as the name is derived from Saba, the capital city of Sabæa, in Arabia, the plant may have been the same as the third form. The second is the form which was then commonly grown in southern Europe and which had been described and figured by many earlier writers. The third, from the description and synonymy, is clearly the white-seeded durra of Arabia mentioned by Avicenna, Rauwolf, and others. Two distinct varieties are here discussed, the common European form with reddish seeds and an Arabian variety with white seeds, the latter probably a form of white durra.

Parkinson (1640) describes sorghum under the title "Melica sive sorghum, Indian Millet." He uses the same figure as several other authors, namely, that of L'Obel. Evidently only one variety is in his thought and that one the common and long-cultivated form. Of the white, flat-seeded variety he makes no mention.

Caspar Bauhin (1658) gives full descriptions of the two sorghums he had merely listed under *Milium arundinaceum* in his "Pinax" (1623). These were the common sorghum of Europe and the white-seeded sorghum of Arabia. The common form he describes as producing from one seed 4 to 5, or more, stout and somewhat sweet culms, with leaves 1½ feet long and 3 to 4 inches wide, and erect heads 9 inches long and 4 to 5 inches in width, containing abundant seeds, mostly reddish or deep red, occasionally pale or yellowish in color. This sorghum had been introduced from India into Spain, Italy, and elsewhere. Bauhin thus holds the sorghum of Europe to be but a single variety or species, the milium indicum of Pliny. His figure is that of Mattioli, sixty years before. The white-seeded form of Arabia, Mesopotamia, and Asia Minor he notes as having a culm similar to corn or sugar cane, 9 to 12 feet high, filled with sweet pith, from which the natives extract, by chewing, a sweet juice, and bearing a beautiful white panicle 6 inches long, containing hard and brilliantly white, flattened seeds. From the white durra now grown extensively in the same region this form apparently differs in two important respects—the sweet juice and the erect heads. Bauhin does not state that the heads are erect, but so striking and unusual a character as pendent heads would certainly have received mention if known to him. It is, however, quite possible that this fact had not become known in Europe, since the plant was cultivated no nearer than Cilicia in Asia Minor. If it is, indeed, the progenitor of the white durra now occupying the same region, the saccharine quality of the juice has been entirely lost.

Hermann (1687) presents the different forms of sorghum in the following manner:

Milium indicum, arundinaceo cauli, granis flavescentibus.
Milium indicum, arundinaceo cauli, granis nigris.
Milium arundinaceum, subrotundo semine, Sorgo nominatum.
Milium arundinaceum, plano alboque semine.

The first two he evidently thought to be new and so described them. The last two are simply quoted on the authority of Bauhin, without description. Hermann seems to think his second variety to be the Indian sorghum of Pliny. He describes it as having black seeds, but does not mention the glumes, while in the first form he speaks of the seeds as pale and the glumes as black and brilliant. Since there are no sorghums with black seeds (grana nigra lucida) it is probable that his two varieties were the same thing, described from hearsay rather than observation. In the first variety the color of the actual seed is given; in the other, the color of the spikelet.

Ray (1688) cites the two varieties of C. Bauhin, omitting *Milium sabaeum*, and copies most of Bauhin's notes on them.

Breyne (1689) discusses sorghum as "Milium Indicum sacchariferum altissimum," and describes two forms having "semine rotundo atro" and "semine ferrugineo," respectively. He is the first author to recognize the saccharine content of the plant in forming a name for it. This work is not accessible, and it is not known what varieties Breyne had in hand.

Sloane, in his "Catalogus" (1696), gives a copious bibliography and synonymy of this plant, including all previous authors.

Morison (1699) places under the generic heading Milium two subgroups: Minus, including wild and cultivated species of Panicum, and majus, including sorghums and probably pearl millet. Of sorghums there are three, the names being quoted from C. Bauhin and identical with those used by him in his "Pinax" (1623). Concerning the white-seeded variety he gives the new and important information that the head is pendent, but has no illustration of it. In his description of *Milium sabaeum* no mention is made of a pendent head, but his figure shows a group of two stalks, one bearing an erect head and the other a pendent head. Both varieties were Arabian, and it is quite possible that they were the same. He is the first author who definitely records a sorghum with a pendent head.

EIGHTEENTH CENTURY WRITERS.

Sloane (1707) gives a description of the Guinea corn of Jamaica. In this connection he supplements the synonymy given in his earlier "Catalogus" by citations from subsequent authors. He states that this form of sorghum was then in very general culture on that island, as it probably was in others of the West Indies. From the brief description, the plant seems to be identical with the variety peculiar to and extensively grown in many of the West Indian islands at the present day under the same name, Guinea corn. It is almost certain that this plant was brought from the west or Guinea coast of Africa with some of the slaves, whose chief food-grain it had been in their African home. It is discussed in this bulletin under the name Guinea kafir (fig. 3, *b*) in the paragraph on the West Indies.

Micheli (1729) proposed the generic name Sorgum for these plants as segregates from the genus Milium of Tournefort. He did not, however, describe any species in this connection, nor did he indicate what plants of Tournefort should be included in his genus. The name stands, therefore, as a nomen nudum. Tournefort in 1700 had simply lumped sorghum with *Panicum miliaceum* as milium, and cited under it all the names given by the two Bauhins with some new ones of his own, which are, however, not worthy of further attention.

Linné (1737) transferred these plants to his recently erected genus Holcus. The common form is treated as *Holcus glumis glabris* and the white-seeded, or durra, variety from Arabia as *Holcus glumis villosis*. For our purposes this work terminates what is called the pre-Linnean period, the next botanical contribution of any great importance being Linné's "Species Plantarum," wherein began in 1753 the general application of a binomial system of nomenclature for plants.

LINNEAN PERIOD, 1753 TO 1850.

Throughout the Linnean period botanists treated the diverse forms of this cultivated plant as botanical species. Nearly thirty species were named and about sixty binomial combinations made.

THE SPECIES OF LINNÉ AND FORSKÅL.

Linné (1753) published two species of sorghum under his exceedingly composite genus Holcus, namely, *Holcus sorghum* and *H. saccharatus*, adding thereto the wild species as *H. halepensis*. The cultivated species were both from India. Under *Holcus sorghum*, described as "glumis villosis seminibus aristatis," he evidently placed the common European sorghum of earlier authors, since he makes his *Holcus glumis glabris* of 1737 a synonym. The Arabian form with flat white seeds is not mentioned at all, either by name or in the synonymy, though by inference it is included in this species. *Holcus* *saccharatus* is described as " glumis glabris seminibus muticis," based on the *Milium indicum granis flavescentibus* of Hermann and the *Milium indicum sacchariferum altissimum seminibus ferrugineo* of Breyne. In the second edition, 1763, it is described as having an erect, subverticillate panicle with wide-spreading or somewhat drooping branches, in contrast with the small, erect, and ovate heads of *Holcus sorghum.* Both species are credited with villous glumes and awned lemmas (flowering glumes), and are distinguished by the size and character of the panicle.

In his " Mantissa " (1771) he restricts the name *Holcus sorghum* to a strain of the ovate-panicled form with green villous glumes, and adds Bauhin's form with flat white seeds as a synonym. He then permits the open-panicled *Holcus saccharatus* to have hairy glumes and awned lemmas also, and describes a new species, *Holcus bicolor*, similar to *H. sorghum*, with glabrous black glumes and globose white seeds, in awned lemmas, transferring his *Holcus glumis glabris* of 1737 to *Holcus bicolor* as a synonym. This new species was said to have come from Persia, which probably indicates that it was an Indian variety perhaps secured through Persia. A similar form is found abundantly in India to-day. It could scarcely have been the white durra of Arabia, etc., because that had pale glumes.

Forskål (1775) added two species from Egypt: *Holcus dochna* and *H. durra*, the specific names being derived from the common names of the varieties in that country. *Holcus dochna* was probably a saccharine or semisaccharine sort, but is not now certainly identifiable. Both Koernicke (1885, p. 310) and Hackel (1889, p. 509) place it as a synonym under *saccharatus.* Forskål does not mention it as saccharine, but the description accords well with that of the sweet forms. His *Holcus durra* included at least two of the three durra varieties common in Egypt to-day, namely, the white seeded (beda) and the brown seeded (ahmar). Indeed, Forskål makes it cover two white-seeded forms, one with greenish glumes and one with brownish glumes. Koernicke (1885, p. 312) places the reddish-brown-seeded sort under the variety *arduini* Gmel. In 1887 he proposed the name *egyptiacus* for the white-seeded form. Hackel follows him in this, placing under his variety *durra* only a yellow-seeded (safra) form; he does not seem to have had the brown-seeded form at all. These three forms, beda, safra, and ahmar, with white, yellow, and brown seeds, respectively, are in common cultivation in Egypt to-day. They are practically identical except for the color of the seed, and really represent but a single botanical variety instead of three.

THE SPECIES OF ARDUINO.

Arduino (1786) published descriptions of six species of sorghum, three of which he considered new, the other three being those described by Linné. All the species are excellently illustrated on folio plates, and the descriptions are more exact and complete than those of any previous author. Arduino's paper had been presented in 1780 and his experiments had been in progress since 1775, and perhaps for a longer period. He was probably the first author to grow and carefully study in the field all the forms he could obtain. His three new species are *Holcus cafer*, *H. cernuus*, and *H. niger.*

His *Holcus cafer* is the most interesting of all, because it was a recent arrival in Italy from "Cafreria" (Natal), in South Africa, which Arduino describes as "an exceedingly vast province of Africa." How it was obtained is not stated. The description and figure show a form with an umbellate panicle, the long, heavily seeded branches drooping in the form of an umbrella (fig. 13). In appearance it is identical with the drooping strain of Planter sorgo now grown in this country, and which is of known Natal origin. We thus have our Planter sorgo antedated by seventy-five years. Arduino's variety was described as 8 feet or more in height, with stalks as large as American corn, 12 or 13 leaves, and an umbrella-like panicle with drooping branches 6 inches long. The heavy stalks, filled with sweet juice, weighed three or four times as much as those of the ordinary forms, and the stems and foliage remained green until frost, even when the heads were harvested. The reddish seeds were considerably exserted from the small hairy glumes. It is the *Sorghum arduini* of Jacquin (Eclog. Gram., pl. 18, 1791); the variety *cafer* of Koernicke (1885, vol. 1, p. 307); and is doubtfully admitted by Hackel (1889, p. 519).

Arduino believed his *Holcus niger* to be the black sorghum of Pliny and Tournefort. He illustrates (fig. 14) a loose, ovate-pyramidal panicle not nearly so lax and spreading as that of *Holcus saccharatus.* It is much like some of our more compacted Amber forms and the Oomseeana of Wray.

Arduino's *Holcus cernuus* (fig. 15) is our white durra, based on the white-seeded variety of Arabia, etc., discussed by so many of the older authors. Arduino is naturally puzzled by the action of Linné in uniting this form with his *Holcus sorghum*, as he did in his "Mantissa" (1771).

In Arduino's interpretation of Linné's *Holcus sorghum* (fig. 12), it is described as from 6 to 8 feet in height and an inch in diameter, with 8 to 10 leaves and an erect, oval, compact panicle full of seeds of various shades of red and yellow, some included and some partly exserted, the lemmas being awned or awnless. Linné's *Holcus saccharatus* (fig. 12) Arduino describes as a tall, slender cane with long, slender leaves and a sparse, lax panicle about a foot long, with drooping branches, awned or awnless spikelets, smooth or hairy glumes, and seed varying from pale yellow to deep red. He states that these three species, *Holcus sorghum*, *H. niger*, and *H. saccharatus*, had long been cultivated in Italy and were very variable. He calls them light yielders of seed. From *Holcus sorghum* floor brooms were made, and from *Holcus saccharatus* all kinds, from whisk brooms to scrubbing brushes. He calls especial attention to the variability of the species *Holcus sorghum* and *H. saccharatus*. While it is likely that other importations than that recorded by Pliny were represented in the forms described by Arduino, it is certain that many of these forms must have arisen through variations and crossing which took place in Europe. For many years thereafter these varying forms were made the basis of new species by the botanists of that period.

NUMEROUS SPECIES OF LATER AUTHORS.

Koeler (1802) founded his genus Blumenbachia on the wild *Holcus halepensis*, but the name was never taken up for the cultivated plant. Brotero (1804) transferred *Holcus sorghum* and *H. halepensis* to the genus Andropogon. Persoon (1805) took up the old generic name Sorghum, first proposed by Micheli, and rechristened the cultivated plant *Sorghum vulgare*. During the first half of the nineteenth century many more cultivated forms were described as new species, until the total number of species was thirty or more. The following is an alphabetical list of the names used for cultivated sorghums described as species: *Albus*, *arduini*, *besseri*, *bicolor*, *cafer*, *caffrorum*, *campanum*, *cernuum*, *commune*, *compactus*, *dochna*, *dora*, *drummondii*, *duna*, *durra*, *dulcis*, *ferrugineus*, *nervosum*, *nigricans*, *niger*, *nigerrimus*, *pyramidale*, *rubens*, *saccharatus*, *sorghum*, *subglabrescens*, *truchmenorum*, *usorum*, *versicolor*, and *vulgare*. Some of these names have been used in all three genera, Holcus, Sorghum, and Andropogon; some have been used in two; others only in one. In this manner a total of fifty-five or sixty binomial combinations has been reached.

Most of these so-called species are quite unimportant. A few of them probably include forms which have since become extensively cultivated in this country. It is almost impossible to identify these species from their meager descriptions, especially those described from regions where sorghums are abundant and variable. In consulting the writings of different authors who discuss a form under the same specific name, it becomes evident that they did not always have the same plant in hand. For example, the name *bicolor* of Linné has at one time or another been applied to almost every form with white seeds and dark glumes. In the same way the name *cernuus* of Arduino has been used for all forms with pendent panicles, without much regard to other characters involved.

RECENT PERIOD, 1850 TO THE PRESENT TIME.

By the middle of the last century the conception of cultivated forms of sorghum as species had been abandoned and the description of them as horticultural and botanical varieties was begun. Olcott (1857) published Leonard Wray's brief descriptions of his recently introduced Natal varieties (fig. 17). Stewart (1867) reprinted these descriptions, but neither attempted any classification.

BEGINNINGS OF CLASSIFICATION.

Pech (1865) published a provisional classification of the few sweet varieties then known to him. Collier (1884) amplified Pech's outline by inserting a number of recently developed saccharine varieties, many of which were local strains that never became generally grown and are not now identifiable. These two classifications were made on a natural basis, and if fuller and more definite would be fairly usable, though wrought out from confessedly imperfect material and insufficient field study and including only a limited number of forms, of which all except one were sorgos.

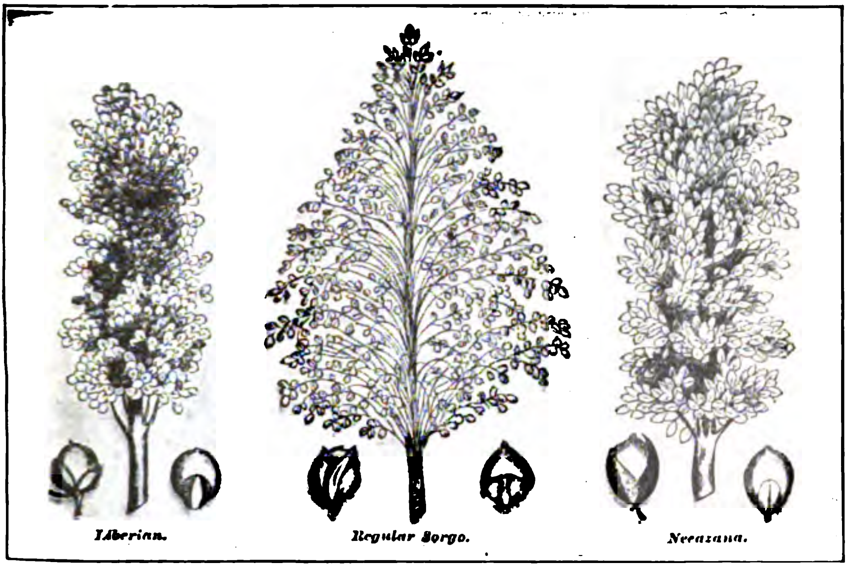

FIG. 17.—Heads of three sorghum varieties figured in 1869. "Liberian" is Wray's Koombana, the present Sumac; "Regular sorgo" is the Chinese variety; and "Neeazana" is the original form of Orange.

Koernicke (1885) presented the first attempted classification of the cultivated forms of the whole world. He recognizes them as comprising a single species *Andropogon sorghum* (L.) Brot., and disposes them in twelve varieties, grouped into two sections, Effusus and Contractus, referring to the habit of the panicle.

The first section includes five varieties: *Cafer* Ard., *technicus* Kcke., *saccharatus* L., *leucospermus* Kcke., and *niger* Ard. The first two varieties are separated from the others by having a much shortened rhachis, or central axis, in the panicle. The variety *cafer* is our Planter sorgo, or a very similar variety, while the variety *technicus* is broom corn. The last three are apparently all sorgos or sweet sorghums. The variety *saccharatus* is much like our most spreading Red Amber, the variety *leucospermus* is not determinable, and the variety *niger* is probably identical with some of our smaller and more compact Amber forms, as Black Dwarf. Koernicke's *leucospermus* had not white seeds, but red, the inappropriate name apparently referring to the pale glumes, due perhaps to the acknowledged late and incomplete maturity of the specimens on which it was based.

The second section contains seven varieties, of which the first four—*usorum* Nees., *arduini* Gmel., *aethiops* Kcke., and *bicolor* L.—had erect heads, and the last three—*cernuus* Ard., *truchmenorum* Koch., and *neesii* Kcke.—had the heads pendent. Of the first group, with erect panicles, the variety *usorum*, with short compact heads, is not certainly identifiable with any of the hundred or more Natal forms studied by the writer. Variety *arduini* is probably our Orange sorgo, variety *aethiops* is not known, though it is perhaps the sorgo form with ovate black heads still grown in central Europe. Variety *bicolor* is not identifiable among the many similar forms of India and equatorial Africa. Considering, now, the three varieties having pendent heads, it is known that the variety *cernuus* includes, among others, our white durra, and that the variety *truchmenorum* is that form of white durra with taller stalks and more compact heads found in Turkestan, where it is called, in Russian, "Dzhugara." Variety *neesii* is a blackhulled white durra from the region of Natal. It has never been found in the recent importations from there.

Hackel (1889) divides *Andropogon sorghum* into two subspecies, *halepensis* and *sativus*, thus including both the wild and the cultivated forms in a single species. His subspecies *sativus* is the *Andropogon sorghum* of Koernicke's classification and the *Sorghum vulgare* of Persoon. He divides this subspecies into nine sections, which contain a total of thirty-six varieties. These nine sections, or groups, are separated largely on such characters as the comparative shape and size of the spikelets, the comparative length and width of the glumes, and the relation of these to the seed. The density of the panicle, the position of its branches, the color of the seeds, and the presence and length of the awn are used as minor determining characters. No mention is made of the size and height of the culms, the character of the juice, the number or size of the leaves, the comparative length of the sheaths and internodes, or of the purpose for which the varieties are grown.

In Africa there naturally has been but little done toward a study of the numberless forms of sorghum. In Egypt the British agricultural officials have studied quite carefully the native varieties, and the writer is much indebted to them for various shipments of seed and for provisional classifications, which are apparently very accurate. Colonial officers in French West Africa[a] (Niger Valley and Senegal) and in German East Africa[a] have published brief notes on the leading varieties of their regions. Schumann (1895), Busse and Pilger (1902), and Pilger (1904) have described botanically a very large number of forms from German East Africa and from Togo on the Guinea coast. Their descriptions are apparently based on dried material, mostly heads. Without the cultivation and field study of varieties for at least two or three seasons, such descriptions are of little value to the agronomist.

In India a comprehensive effort to assort, classify, and describe the manifold forms of that extensive region is now being made. Hooker (1897) gives a synopsis of the varieties of India as outlined by Hackel and also by Stapf. The Reporter on Economic Products for India, Mr. I. H. Burkill, has been engaged for several years in this work. A synopsis of a portion of his outline of classification was published by Benson and Subba Rao (1906) with valuable additions of their own. For the varieties of the Madras Presidency, occupying the southern portion of the peninsula, these last-named gentlemen have made a provisional classification, which has the decided merit of taking into account the agronomic characters of the plants.

In recent years the number of trinomials and other polynomials applied to sorghum varieties has been increased to literally hundreds. It is an open question whether any useful purpose is subserved by the wholesale application of Latin trinomials to the exotic cultivated forms of a variable plant like sorghum, especially where the study is limited to immature or fragmentary dried material. Where a field study of the growing plants is also made, the final number of varieties is always greatly reduced and the practice becomes less objectionable.

A satisfactory classification of the varieties of sorghum or of any other cultivated plant must take account of the habit and characters of the entire plant, not merely of the panicles. The height, size, and color of the stalks, the comparative length of the internodes and sheaths, the number, size, and color of the leaves, the length, stoutness, and exsertion of the peduncle, and the number of branches and suckers are all of vital importance in the study of varieties. Comparative earliness, disease resistance, drought resistance, and productiveness, with other available ecologic characters, ought to be included.

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[a] Dumas, 1905, and Lambrecht, 1903.

Furthermore, the use of purely artificial keys must be given up and natural groupings substituted before much permanent good can come from any classification of cultivated varieties. The lumping of all the forms which happen to have white seeds or spreading branches or pendent panicles only adds to present confusion. It is necessary first to define the major natural groups which agronomic and botanic studies have shown to exist, even if such groups can not always be sharply separated by a single character. When this has been done the varieties in each group should be distinguished by the most obvious natural characters. In this way only can we hope to prepare the usable and instructive systems of classification so much needed for the varieties of all our widely disseminated and variable cultivated crops.

SUMMARY.

AGRICULTURAL HISTORY AND DISTRIBUTION.

All cultivated sorghums are held to have been derived from the wild species *Andropogon halepensis.*

Many facts point to an independent origin in tropical Africa and in India, which are the two great centers of sorghum production, each occupied by an enormous number of varieties.

Sorghums, as crops cultivated for human food, date from the most remote historic times.

In varying forms sorghum is found abundantly throughout Africa and across the southern half of Asia. It is less abundantly distributed in southern Europe and in the United States and the West Indies.

Sorghum varieties furnish the chief cereal food of the native millions in Africa.

In British South Africa kafirs and sorgos are the predominating groups, represented by numerous varieties. Most of the kafirs and sorgos cultivated in the United States were obtained in this region, which is similar in many respects to much of our Great Plains area.

Throughout equatorial Africa some new and little-known groups, related to the durras, are the leading types. Forms of the Roxburghii group also occur commonly, while kafirs and sorgos are rare. All these tropical forms are late in maturing.

In Abyssinia and throughout the Sudan these new durra-like groups predominate. The Roxburghii group diminishes in importance, while kafirs and sorgos disappear as native types. Few of the local varieties are immediately adapted to our conditions.

In North or Mediterranean Africa only durra groups are found. Those forms found in Egypt are Sudanese; the white durra in the

Barbary States is nearly identical with that of southwestern Asia, and doubtless has resulted from the Arab invasion of Africa.

In all of southwestern Asia, including Asia Minor, Syria, Arabia, Turkestan, and perhaps a part of Persia, the single variety is a white durra, equivalent to our American form.

India contains a bewildering confusion of little-known forms. Many of them approximate the durra group; many are forms of shallu, the type of the Roxburghii group; while some represent entirely new groups of sorghum. A large number tested in this country have proved very poor yielders of grain.

East China and Manchuria are the home of a new group, the kowliangs, with several well-marked varieties. One sorgo variety has long been cultivated at the mouth of the Yangtze River. All these are well adapted to growth under the conditions obtaining in our sorghum belt.

The larger islands near the coast of Asia show a few forms, apparently derived from the mainland.

Europe received a sorghum variety from India during the first century, A. D. Only two or three forms of the sorgo type had been obtained, either through importation or evolution, up to about one hundred and thirty years ago. Only broom corn and a few sorgos are now found there.

No cultivated sorghums are native to the New World. Probably the earliest introduction was the Guinea kafir in the West Indies.

Scattering introductions have appeared in the United States since early colonial days. With the exception of broom corn, none was permanent until the arrival of the sorgo group about fifty-five years ago, followed by the durras and kafirs about twenty years later, shallu about twenty years ago, and the kowliangs recently.

BOTANICAL HISTORY AND CLASSIFICATION.

Sorghum was first known in Europe as *Milium indicum*, or Indian millet, in reference to its origin. Many similar names were applied later.

The common name sorghum, or sorgo, was derived more than three hundred and sixty years ago from the Latin word "surgo," meaning to rise or tower, in reference to the height of sorghums in comparison with that of other crops.

During the sixteenth, seventeenth, and eighteenth centuries the European forms were named and described, with occasional figures, by many pre-Linnean botanists.

The earliest accepted binomial is *Holcus sorghum* L., 1753.

By the middle of the nineteenth century fully thirty botanical species had been described from cultivated forms and about sixty binomial combinations had been made.

Only a part of these so-called species can be identified with existing available forms to-day.

Since about 1850 the differing forms of cultivated sorghums have been regarded as botanical or horticultural varieties. Descriptions have commonly been drawn from the heads and seeds only, ignoring the characters of the plant.

During the past half century numerous classifications of varying scope and completeness have been constructed. Any satisfactory classification must take account of the habit and characters of the entire plant and have regard for natural groups.

BIBLIOGRAPHY.

600 B. C. (about). Bible. Book of Ezekiel, chapter 4, verse 9.

60 or 70 A. D. (about). Plinius, Gaius (Secundus). Naturalis historiæ, book 18, chapter 7 (vol. 2, p. 424, edition of 1568).

1537. Rüel, Jean. De natura stirpium, p. 320.

1542. Crescenzi, Piero de (Petrus de Crescentiis). D'agricoltura, book 3, chapter 17 (Italian edition of 1542; the original is said to have been written about 1300 A. D.).

1542. Fuchs, Leonhard. De historia stirpium, p. 772 (colored figure).

1552. Tragus (Bock), Hieronymus. De stirpium, pp. 659–660 (figure).

1556. Scaliger, J. C. Exotericarum exercitationum, p. 869.

1576. L'Obel (Lobelius), Mathias de. Plantarum seu stirpium historia, p. 25 (figure).

1583. Dodoens (Dodon), Rembert. Stirpium historiæ pemptades sex sive libri XXX, p. 499 (figure).

1583. Cæsalpini, Andrea. De plantis, p. 181.

1592. Porta, Giambattista. Neapolitani villæ, p. 865.

1598. Mattioli, Pietro Andrea. Opera, quæ extant, omnia, p. 329 (figure).

1605. Belon (Bellonius), Pierre. Les observations (Latin translation by Clusius in his Exoticorum libri decem, vol. 2, p. 154).

1613. Besler, Basil. Hortus eystettensis opera.

1623. Bauhin, Caspar. Pinax theatri botanici, pp. 26–27.

1640. Parkinson, John. Theatrum botanicum, vol. 2, pp. 1136–1137 (figure after L'Obel).

1658. Bauhin, Caspar. Theatri botanici sive historiæ plantarum, pp. 510–516.

1687. Hermann, Paul. Catalogus horti academici Lugduno Batavi, pp. 425–426.

1688. Ray, John. Historiæ plantarum, vol. 2, pp. 1252–1253.

1689. Breyne, Jacob. Prodromus rariorum plantarum, vol. 2, p. 72.

1696. Sloane, Hans. Catalogus plantarum Jamaicæ, p. 25.

1699. Morison, Robert. Plantarum historiæ universalis Oxoniensis, vol. 3, p. 196 (figures, sect. 8, plate 5, not 11 as usually cited).

1700. Tournefort, Joseph Pitton. De institutiones rei herbariæ, vol. 1, pp. 514–515.

1707. Sloane, Hans. Historia naturalis Jamaicæ, vol 1, p. 104.

1729. Micheli, Pier' Antonio. Nova plantarum genera, p. 35.

1737. Linné, Carl. Hortus Cliffortianus, pp. 468–469.

1753. Linné, Carl. Species plantarum, p. 1047.

1763. Linné, Carl. Ibid., ed. 2.

1771. Linné, Carl. Mantissa, vol. 2, p. 301.

1775. Forskål, Pehr. Flora Egyptiaco-Arabica, p. 174 (Niebuhr edition).

1786. Arduino, Pietro. Saggi scientifici e letterari dell' accademia di Padova, vol. 1, pp. 119–140, plates 1–6 (excluding species 2 and plate 2).

1791. Gmelin, J. F. Systema vegetabilium, p. 174.

1802. Koeler, G. L. Descriptio graminum in Gallia et Germania, p. 28.

1804. Brotero, Felix de Avellar. Flora lusitanica, vol. 1, pp. 88–89.

1805. Persoon, C. H. Synopsis plantarum, vol. 1, p. 101.

1841. Nees ab Esenbeck, C. G. Floræ Africæ Australioris, pp. 85–87.

1848. Koch, C. "Sorghum truchmenorum," in Koch, K., Beitrage zu einer Flora des Orientes. Linnæa, vol. 21, pp. 442–443.

1857. Olcott, Henry J. Sorgho and imphee, New York, pp. 204–212.

1865. Pech, F. Botanical history of sorghum. U. S. Department of Agriculture Report, 1865, pp. 299–307 (7 figures).

1865. Collins, Varnum D. Sorgo, or North Chinese sugar cane. Journal North-China Branch Royal Asiatic Society, n. s., vol. 2, pp. 85–98. December, 1865.

1867. Stewart, F. L. Sorghum and its products, Philadelphia, pp. 210–222.

1884. Collier, Peter. Sorghum: Its culture and manufacture, Cincinnati, pp. 50–101 (plates 1–15 and frontispiece).

1885. Hackel, E. Die kultivirten Sorghum-Formen und ihre Abstammung. Engler, Botanische Jahrbücher, vol. 7, pp. 115–126.

1885. Koernicke, Friedrich. "Andropogon sorghum, Brot., Die Mohrhirse," in Koernicke, F., and Werner, H., Handbuch des Getreidebaues, vol. 1, pp. 294–315 (plate 9, figures 43 and 44).

1885. Werner, Hugo. "Mohrhirse. Andropogon sorghum, Brot.," in ibid., vol. 2, pp. 909–917.

1886. Wönig, Franz. Die Pflanzen in alten Aegypten, pp. 171–174.

1887. Koernicke, F., in Ascherson, P., and Schweinfurth, G., Illustration de la flore d'Egypte. Memoires de l'Institut Egyptien, vol. 2, pp. 163–165.

1889. Hackel, E. "Andropogoneæ," in De Candolle, Monographiae phanerogamarum, vol. 6 (sorghum, pp. 499–520).

1893. Watt, George. "Sorghum," in A dictionary of the economic products of India, vol. 6, pp. 277–317.

1893. Bretschneider, Emil. Botanicon sinicum II. Journal China Branch, Royal Asiatic Society (1890–91), n. s., vol. 25, pp. 147–148.

1895. Georgeson, C. C. Kansas Agricultural Experiment Station Bulletin 56, pp. 161–168.

1895. Schumann, K. "Durra oder Mohrhirse," in Engler, Die Pflanzenwelt Ostafrikas und der Nachbargebiete, part B, pp. 34–50.

1896. Georgeson, C. C. Kafir corn; Characteristics, culture, and uses. Farmers' Bulletin 37, U. S. Department of Agriculture, pp. 1–11.

1897. Hooker, J. D. Flora of British India, vol. 7, pp. 182–184.

1899. Cook, O. F. Seeds of saccharine sorghums distributed by the Section of Seed and Plant Introduction. Inventory No. 3, Division of Botany, U. S. Department of Agriculture.

1900. Georgeson, C. C. Kafir-corn. Kansas Agricultural Experiment Station Bulletin 93, pp. 29–48, March, 1900.

1902. Ball, Carleton R. Johnson grass: Report of investigations made during the season of 1901. Bulletin 11, Bureau of Plant Industry, U. S. Department of Agriculture, pp. 7–11.

1902. Busse, W., and Pilger, R. "Ueber Culturformen der Sorghum-hirse aus Deutsch Ostafrika und Togo," in Engler, Botanische Jahrbücher, vol. 32, pp. 182–189.

1903. Lambrecht. Ueber die Landwirtschaft der Eingeborenen im Bezirk Kilossa. Berichte über Land- und Forstwirtschaft in Deutsch-Ostafrika, vol. 1, pp. 391–402.

1905. Dumas, P. Culture du sorgho dans les vallées du Niger et du Haut Sénégal. L'Agriculture Pratique des Pays Chauds, vol. 5 (Jan.–June), pp. 458–466; (July–Dec.), pp. 8–21. 1905. (Reprinted, 27 pp., Paris, 1906.)

1906. Ball, Carleton R. Saccharine sorghums for forage. Farmers' Bulletin 246, U. S. Department of Agriculture, pp. 7–18.

1906. Benson, C., and Subba Rao, C. K. The great millet or sorghum in Madras. Bulletin, Department of Agriculture, Madras, India, vol 3 (no. 55), pp. 64–91.

1906. Burkill, I. H. (A portion of a provisional classification is published by Benson and Subba Rao, loc. cit.)

1906. Watt, George. Sorghum vulgare, Pers. The great millet or juar in India. Agricultural Ledger, 1905, pp. 83–90 (agric. series, no. 37, pp. 91–97).

1907. Warburton, C. W. The nonsaccharine sorghums. Farmers' Bulletin 288, U. S. Department of Agriculture, pp. 8–10.

1907. Ball, Carleton R. Sorghum. Cyclopedia of Agriculture, edited by L. H. Bailey, vol. 2, pp. 574–580 (figures 808–814).

1908. Ball, Carleton R. Milo as a dry-land grain crop. Farmers' Bulletin 322, U. S. Department of Agriculture, pp. 5–10.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 176.

B. T. GALLOWAY, *Chief of Bureau.*

SEEDS AND PLANTS IMPORTED

DURING THE PERIOD FROM JULY 1 TO SEPTEMBER 30, 1909:

INVENTORY No. 20; Nos. 25718 to 26047.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., December 24, 1909.

SIR: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 176 of the series of this Bureau, the accompanying manuscript, entitled "Seeds and Plants Imported during the Period from July 1 to September 30, 1909: Inventory No. 20; Nos. 25718 to 26047."

This manuscript has been submitted by the Agricultural Explorer in Charge of Foreign Seed and Plant Introduction with a view to publication.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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B. P. I.—541.

SEEDS AND PLANTS IMPORTED DURING THE PERIOD FROM JULY 1 TO SEPTEMBER 30, 1909: INVENTORY NO. 20; NOS. 25718 TO 26047.

INTRODUCTORY STATEMENT.

This inventory, covering the first quarter of the fiscal year from July 1 to September 30, 1909, contains 329 introductions. The first quarter has always been light, so far as the number of introductions is concerned. This quarter's introductions have been unusually so, owing to the fact that no explorers were in the field and changes in the office force interfered with regular correspondence; further, to the fact that only those introductions deemed of special interest are being included, those considered of minor importance being recorded in the office files only.

Of unusual interest in this inventory might be mentioned the following introductions:

Numbers 25858 and 25859 cover the seeds of the rattan palms which supply the valuable material for the manufacture of cane-seated chairs, street-car seats, baskets, etc., and whose cultivation as a tropical crop seems to have been given very little attention. The ability of these climbing palms to thrive in dense jungles is believed to be worthy the attention of tropical planters in the Western Hemisphere.

An importation of seeds of the "Queensland nut," *Macadamia ternifolia* (No. 25845), calls attention to the possibilities of cultivating this plant in parts of California and southern Florida. Trees are now growing in southern California which have borne nuts for the past two seasons. The Macadamia is being cultivated in Queensland and New South Wales, and, according to our information, the nuts are very well liked in Sydney, where they retail for as much as a shilling a pound.

In order to aid in the experiments with the horse bean, *Vicia faba*, which are being carried on by the Office of Forage-Crop Investigations, a collection of this important winter legume, adapted to the mild winters of the Southwestern States, has been gathered together from India, Egypt, Holland, Hungary, China, Kashmir, and Spain, and it is hoped that more definite information can be secured regarding the adaptability of this crop to our southwestern country.

The "Monketaan" stock melon (No. 25934) comes to us recommended by Mr. Lounsbury and Mr. Thornton, of the Department of

Agriculture of Cape Colony, as a plant worthy of being given unusual attention. According to their statements, this melon, which is of the nature of a watermelon, is quite distinct from the well-known Tsama melon, which grows on the west side of the Kalihari desert. This is found on the east side of the desert and is remarkable for the high yield of melons to the acre. As many as 150 tons have been produced to the acre, 75 tons being not at all unusual.

The interest in new varieties of mangos has become general enough in Florida to warrant our calling particular attention to the "Pahutan" mango (No. 25940), introduced by Mr. William S. Lyon from the Philippines. Although not as large a fruit or as small seeded as some of the East Indian mangos, it fruits early and is enormously prolific (which some of the East Indian varieties are not). According to Mr. Lyon its sweetness and juiciness are unapproached by any other of the many Filipino mangos he has eaten. Its thick skin will probably make it a good shipper.

The oriental *Myrica nagi* has been introduced under No. 25908. This extremely interesting fruit plant, whose dark wine-colored fruits are exceedingly ornamental, has not been given the attention which it deserves. There seem to be a number of varieties of this fruit, and, although it is a slow-growing tree and late coming into bearing, it is deserving of a trial in California and northern Florida.

The great value of a variety of cherry which is hardier in fruit bud than other cherries is conceded by the horticulturists of the North western States. Those who are breeding or experimenting with cherries will therefore be interested in the introduction of *Prunus tomentosa* (No. 25880), which has been especially recommended by Professor Macoun, of the Experimental Farm at Ottawa, Canada Trees of this species have been placed in the Upper Mississippi Valley Plant Introduction Garden at Ames, Iowa, for further trial and propagation.

Of especial interest and problematic value is a collection of peach apricot, and cherry seeds from the Himalayas (Nos. 25894 to 25896) The Indian bael fruit (Nos. 25879, 25889, 25890, and 25912) is one which may prove valuable for making sherbets and for the flavoring of soft drinks. A collection of varieties of tropical corn, representing some of the best work done by the Harvard Experiment Station in Cuba; a collection of oats from Algeria, Palestine, Sweden, and Turkey for the oat breeders; and a wild olive, *Olea foveolata* (No. 25846) from the East London district of Cape Colony, are also worthy o special mention.

DAVID FAIRCHILD,
Agricultural Explorer in Charge.

OFFICE OF FOREIGN SEED AND PLANT INTRODUCTION,
Washington, D. C., December 24, 1909.

INVENTORY.

25718 to 25722.

From Cartago, Costa Rica. Presented by Mr. C. Wercklé. Received July 2, 1909.

Seeds of the following; descriptive notes by Mr. Wercklé.

25718. ANACARDIUM OCCIDENTALE L. **Cashew.**

"These seeds are from the best and largest varieties I could find; red, yellow, and tawn color, the latter are the best. They are from the large grove of Don Rafael Yglesias, in the Cazalar."

25719. CUCURBITA MOSCHATA Duch.

"*Pipian.* Most prolific pumpkin of the Pacific coast. Full; white fleshed."

25720. CARICA PAPAYA L. **Papaw.**

"Good, very large variety."

25721. CARICA PELTATA Hook. & Arn.

"*Suara.* Fruit very small, globular, full (no cavity), sweet, and fragrant. For crossing. Eaten with the seeds as Granadilla. Ovary full, on account of formation of cellular tissue on the funiculus the funiculi of the center of the placenta are very long. Pulp soft, skin very thin."

Distribution.—A native of Central America, found on the coast of Nicaragua and Costa Rica.

25722. CARICA PAPAYA ♀ × peltata ♂

"Small, sweet, fragrant fruits, not full or solid as the *Suara.*"

25723 and 25724.

From Baroda, India. Presented by Mr. B. F. Cavanagh, superintendent, State Gardens. Received July 3, 1909.

Seeds of the following:

25723. TERMINALIA BELLERICA (Gaertn.) Roxb.

See S. P. I. No. 25541 for description.

25724. PHYLLANTHUS EMBLICA L.

"A small deciduous tree of the family Euphorbiaceæ, found in China, Japan, India, and elsewhere. The unripe fruit, formerly official in medicine, is known commercially as emblic myrobalans and with the leaves and bark is used in tanning. The leaves have been found to contain 18 per cent tannin and the bark 12.6 per cent. Introduced for trial in the Southern States." (*W. W. Stockberger.*)

Distribution.—A large tree, native of tropical India, China, and the Malay Archipelago.

25725 to 25728.

From Baroda, India. Presented by Mr. B. F. Cavanagh, superintendent, State Gardens. Received July 6, 1909.

25725 to 25728—Continued.

Seeds of the following:

25725. STIZOLOBIUM sp.

25726 to 25728. DOLICHOS LABLAB L. **Bonavist bean.**

25726. Black.

25727. Large red.

25728. Small red.

25729. PHASEOLUS LUNATUS L.

From Antigua, Leeward Islands, West Indies. Presented by Mr. S. Jackson, curator, Government Botanic Station. Received July 3, 1909.

"*Barbuda bean.*"

25730 and 25731. AVENA spp. **Oat.**

From Jerusalem, Palestine. Presented by Mr. E. F. Beaumont. Received July 6, 1909.

Seeds of the following:

25730. AVENA STERILIS L.

25731. AVENA SATIVA L.

Grown from Jaffa seed.

25732. STIZOLOBIUM sp.

From Lawang, Java. Presented by Mr. M. Buysman. Received July 10, 1909.

Black seeded.

25733. MEDICAGO SATIVA L. **Alfalfa.**

From Bridgeport, Kans. Grown on the farm of Mr. Carl Wheeler. Numbered for convenience in recording distribution, July 12, 1909.

"A plant selected for leafiness and seed production from same field which produced S. P. I. No. 19508. Grown at the Department greenhouse under Agros. No. 20." (*J. M. Westgate.*)

25736. ZEA MAYS L. **Corn.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received July 16, 1909.

"*Hickory King.* A strain now being developed in South Africa." (*Davy.*)

25738. SACCHARUM OFFICINARUM L. **Sugar cane.**

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 2, 1909.

"Arrows of one of our best varieties of sugar cane (G. Z. No. 247). Rather a large percentage of these seeds do not germinate." (*Treub.*)

25740. PANICUM PALMAEFOLIUM Koen.

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received July 19, 1909.

"I do not consider this one of our best grasses, but it is a useful sort in shady places, in comparatively warm districts, and in forest glades." (*Davy.*)

Distribution.—A native of tropical Africa, and extending to the Cape.

25742 to 25752.

From Bavaria, Germany. Presented by G. & S. Heil, Tückelhausen, near Würzburg, Bavaria, through Mr. Charles J. Brand. Received June, 1909.

Seeds of the following:

25742 and 25743. HORDEUM DISTICHON NUTANS Schubl. **Barley.**

25742. *Heil's Hanna No. 4.*

25743. *Heil's Hanna No. 2.*

25744 and 25745. HORDEUM DISTICHON L. **Barley.**

25744. *Original Franconian No. 1.*

25745. *Heil's Improved Franconian.*

25746 and 25747. HORDEUM DISTICHON NUTANS Schubl. **Barley**

25746. *Heil's Hanna No. 1.*

25747. *Heil's Hanna No. 3.*

25748. TRITICUM AESTIVUM L. **Wheat.**

Rimpau's Red Schlanstetter Summer.

25749 and 25750. AVENA SATIVA L. **Oat.**

25749. *Svalöfs Ligowo.*

25750. *Beseler No. 2.*

25751. TRIFOLIUM PRATENSE L. **Red clover.**

German.

25752. BETA VULGARIS L. **Sugar beet.**

Remlingen.

25753. STIZOLOBIUM sp.

From Calcutta, India. Procured by Mr. William H. Michael, American consul-general, who purchased the seed from Mr. S. P. Chatterjee, seedsman. Received July 23, 1909.

Mottled brown and black.

25754. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Tamsui (Daitotei), Formosa, Japan. Presented by Mr. Carl F. Deichman, American consul. Received July 26, 1909.

"Seeds of a watermelon growing in the island of Formosa, which has a fairly good flavor and I believe with proper cultivation could be much improved in quality. The meat of the melon is a very pretty shade of yellow, from lemon to light-orange color, and the size averages about 12 inches in diameter. It would, no doubt, be quite acceptable in the larger restaurants of New York, where there is always a demand for something out of the ordinary. It is not rare here." (*Deichman.*)

25755 to 25757. STIZOLOBIUM spp.

From Reduit, Mauritius. Presented by Dr. P. Boname, director, Agricultural Station. Received July 26, 1909.

Seeds of the following:

25755. Black.

"This is the most extensively cultivated and seems to be the most vigorous." (*Boname.*)

25756. Greenish yellow.

25757. Yellowish, mottled with brown.

25758 to 25774. ZEA MAYS L. **Corn.**

From Ecuador. Presented by Mr. H. R. Dietrich, American consul-general, Guayaquil, Ecuador. Received July 10, 1909.

Seeds of the following; descriptive notes by Mr. Dietrich.

25758. "Maiz amarillo grueso de Chillo (thick, yellow Chillo maize). Grown near Quito, Ecuador, at an elevation of about 8,500 feet, in rich, black, loamy soil. Does well with moderate moisture and is considered to produce better than any other variety grown in Ecuador."

25759. "Maiz blanco (white maize). Grown near Quito, Ecuador. Not quite as productive as some other varieties. It is claimed a good grade of meal may be made from it."

25760. "Maiz morocho blanco (white 'twin' maize). Grown on the hacienda 'Montezerin,' parish of Guayllabamba, near Quito, Ecuador. Elevation, 7,500 feet; moderately warm climate; sandy loam soil, very moist on account of heavy rains. Produces fairly well."

25761. "Maiz morocho grueso de Chillo, blanco (thick 'twin' Chillo maize, white). Grown near Quito, Ecuador. Large, white, and hard; grown at an elevation of 8,500 feet. Rich, black soil; moderate rainfall; produces well."

25762. "Maiz morocho blanco is a type of the hard maize and is distinctive by the better quality of its chemical composition. It acquires greater proportions than other kinds and is as productive as the best varieties grown in Ecuador, but is somewhat slow in its growth and more dependent upon the conditions of the soil than other varieties. From this, it is claimed, comes the variety belonging to the hotter climates. This variety is grown in a different locality in Ecuador than numbers 25760, 25761, and 25763."

25763. "Maiz morocho amarillo is a type of the hard maize and is distinctive by the better quality of its chemical composition. It acquires greater proportions than other kinds and is as productive as the best varieties grown in Ecuador, but is somewhat slow in its growth and more dependent upon the conditions of the soil than other varieties. From this, it is claimed, comes the variety belonging to the hotter climates. This variety is grown in a different locality in Ecuador than numbers 25760 to 25762."

25764. "Maiz amarillo (yellow maize). Grown at Tumbaco, east of Quito, Ecuador, at an elevation of 8,000 feet. Soil, sandy loam; average rainfall; produces well."

25765. "Maiz amarillo (yellow maize). Grown on the hacienda Tina, parish of Conocoto, near Quito, Ecuador, at an elevation of 9,000 feet, in black soil. Does well with moderate rainfall."

25766. "Maiz delgado amarillo (thin, yellow maize). From parish of Quinche, near Quito, Ecuador. Grows in mixed or black sandy soil at an elevation of about 8,000 feet when abundant rain falls."

25767. "Maiz delgado pintado (thin, painted maize). From parish Pomasqui, near Quito, Ecuador. Elevation 8,000 feet; sandy soil; average rainfall; produces well."

25768. "Maiz del indio (the Indian's maize). Grown on the table-lands in the interior of Ecuador."

25769. "Maiz Cangil. Grown on the table-lands in the interior of Ecuador."

25770. "Maiz amarillo de Chillo (yellow Chillo maize). Grown on the tablelands in the interior of Ecuador."

25758 to 25774—Continued.

25771. "Maiz negro (black maize). Grown on the table-lands in the interior of Ecuador."

25772. "Maiz amarillo comun (common yellow maize). Grown on the table-lands in the interior of Ecuador."

25773. "Maiz Chulpi. Grown on the table-lands in the interior of Ecuador."

25774. "Mixed corn grown on the low land near Guayaquil. Used for all purposes for which corn may be used."

25775. JATROPHA sp.

From Vera Cruz, Mexico. Presented by Mr. William W. Canada, American consul. Received July 23, 1909.

"This seed came from a tree that grows wild in the lowlands of this district, is very abundant, and apparently also very rich in oil. The local name is *Duraznillo*, and its commercial value, if any, is unknown here." (*Canada.*)

25776. LAWSONIA INERMIS L.

From Ancon, Canal Zone, Panama. Presented by Mr. H. F. Schultz, horticulturist. Received July 23, 1909.

"This plant has proved very valuable here as an ornamental and flowering shrub. The individually small and rather insignificant yellow flowers form a compact, and yet graceful, panicle and are produced in great masses between the small fine foliage. The plant often produces flowers the first year and abundantly after that. The fragrance is very strong, somewhat resembling that of *Cestrum nocturnum*, and, like the latter, is exhaled even more strongly in the evenings, from which characteristic it has obtained its local name *Dama del noche*.

"Although I do not know whether this plant has ever been used for the manufacture of perfume I should think that it would be suitable for that purpose in frost-free regions of the United States." (*Schultz.*)

"Known as henna, is a shrub long cultivated in the Orient, especially in Egypt and Arabia, where it is used for a variety of purposes. The flowers serve as a perfumery material by virtue of a volatile oil which they contain, having an odor said to closely resemble that of the tea rose. Besides their use in applications to wounds, sores, etc., the leaves are used in some regions to color the finger nails red. The root is astringent." (*R. H. True.*)

Distribution.—Probably a native of the northern part of Africa and western Asia; generally cultivated throughout the warmer parts of Asia and Africa.

25777. ZIZYPHUS JUJUBA (L.) Lam.

From Paris, France. Purchased from Vilmorin-Andrieux & Co. Received July 27, 1909.

Procured as a stock for *Zizyphus sativa*, Chinese date. See S. P. I. Nos. 23439 to 23446 for description.

25778 to 25781. GLYCINE HISPIDA (Moench) Maxim. **Soy bean.**

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 19, 1909.

Seeds of the following:

25778. Black.

25779. Yellow.

25780. Yellow.

25781. Brown.

25782 and 25783. ALBIZZIA spp.

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 24, 1909.

Seeds of the following:

25782. ALBIZZIA STIPULATA Boiv.

A large, deciduous, fast-growing tree, whose wood is used for manufacturing cart wheels, wooden bells, cabinetwork, and furniture, as well as for fuel; the branches are used for fodder, and the trunk yields a gum, which is used for sizing paper. It is a native of India and the Malay Archipelago, and widely distributed in tropical and subtropical Asia.

25783. ALBIZZIA MOLUCCANA Miq.

A tree with large compound leaves, and bearing flowers in small globular heads. The stamens are long and form an ornamental ball around the head of the flowers. The pods are long and strap shaped. It is a native of the Molucca Islands.

25784. AVENA STERILIS L. **Oat.**

From Mustapha-Alger, Algeria. Presented by Dr. L. Trabut, Government Botanic Gardens. Received July 26, 1909.

"Variety *sub-sativa*. A cultivated oat developed by utilizing the spontaneous mutations of *Avena sterilis*." (*Trabut.*)

25785 to 25788.

From Amani, Hafen Tanga, German East Africa. Presented by Dr. A. Zimmermann, Royal Agricultural Institute. Received July 24, 1909.

Seeds of the following:

25785 to 25787. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

25785. Reddish brown.

25786. Brown, speckled with black.

25787. Mottled brown.

25788. PENNISETUM AMERICANUM (L.) Schum. **Pearl millet.**

25797 and 25798.

From Buenos Aires, Argentina. Presented by Dr. Carlos Thays, director, Botanical Garden. Received July 19, 1909.

Seeds of the following:

25797. ASPIDOSPERMA QUEBRACHO-BLANCO Schlecht. **Quebracho-blanco.**

"An evergreen tree of the family Apocynaceæ, native of Argentina. The leaves are said to contain 27 per cent tannin. The bark, variously estimated as containing from 2 to 11 per cent tannin, has been used in leather making. The bark contains also 6 alkaloids, one of which, aspidiospermine, is regarded as of most importance as a drug." (*W. W. Stockberger.*)

Distribution.—A large tree, native of the valley of La Plata River in Argentina.

25798. SCHINUS HUIGAN Molina.

"This tree, of the family Anacardiaceæ, is a native of South America, and is closely related to the 'pepper tree' cultivated in California. It has been said to yield 19 to 20 per cent tannin, and according to Siewert the leaves are used in South America as a tanning material." (*W. W. Stockberger.*)

Distribution.—A native of South America, being found in Brazil, Argentina, Uruguay, Chile, and Peru.

25799 to 25802.

From Saigon, Cochin China. Presented by Mr. Jacob E. Conner, American consul. Received July 30, 1909.

Seeds of the following:

25799. CANANGA ODORATA (Lam.) Hook. f. & Thom. **Ilang ilang.**

See S. P. I. No. 22744 for description.

Distribution.—A native of Java and the Philippine Islands, and cultivated in India and other tropical countries.

25800. CRINUM ASIATICUM L.

"I consider this one of the most ornamental plants I know for a lawn or a large jardinière." (*Conner.*)

Distribution.—Native and cultivated throughout tropical India and Ceylon.

25801. DIPTEROCARPUS DYERI Pierre.

"*Dau song nang.*"

Distribution.—A large tree of the valley of the Donnai River, in the region around Saigon, Cochin China.

25802. DIPTEROCARPUS PUNCTULATUS Pierre.

"*Dau do.*"

Distribution.—Same as No. 25801.

25803. CAESALPINIA NUGA (L.) Ait.

From Luzon, Philippine Islands. Presented by Mr. William S. Lyon, Manila, P. I. Received July 30, 1909.

"A very attractive and sweet-scented, flowered, scandent shrub." (*Lyon.*) See S. P. I. No. 20944 for previous introduction and description.

Distribution.—A native of the southern part of Asia, and extending through the Malay Archipelago and Polynesian Islands to Australia.

25804 to 25807. MEDICAGO SATIVA L. **Alfalfa.**

From Mitchell, S. Dak. Presented by Prof. W. A. Wheeler, through Mr. Charles J. Brand. Received July 31, 1909.

Seeds of the following:

25804. "(South Dakota No. 162.) *Grimm* alfalfa, crop of 1908. Originally grown at Külsheim, near Tauberbischofsheim, Baden, Germany. (See S. P. I. No. 24767.) Brought to Carver County, Minn., in 1857, and grown there since 1858. Present sample grown at Mitchell, S. Dak., in 1908, from seed secured in Carver County, Minn., in 1904, and grown at Highmore, S. Dak., 1905 to 1906. Highmore seed taken to Mitchell, S. Dak., in 1907, where it has since been grown. The 1907 crop of this same strain, grown at Mitchell, S. Dak., is under experiment under P. L. H. Nos. 3329 and 3331." (*Brand.*)

25805. "(South Dakota No. 164.) Acclimatized *Turkestan* alfalfa, crop of 1908. Originally imported from Tashkent, Turkestan, in 1898, under S. P. I. No. 991. Grown at Brookings, S. Dak., from 1898 to 1904. Brookings seed taken to Highmore, S. Dak., and grown there from 1905 to 1906. Highmore seed taken to Mitchell, S. Dak., and grown there since 1907. The 1907 crop of this number is under experiment under P. L. H. No. 3330." (*Brand.*)

25804 to 25807—Continued.

25806. "(South Dakota No. 167.) Of unknown origin. Purchased from a seed dealer at Hartford, S. Dak., in 1894, and grown near Baltic, S. Dak., from 1894 to 1904. Baltic seed grown at Highmore, S. Dak., from 1904 to 1906. Highmore seed grown at Mitchell, S. Dak., from 1907 to the present time. Seed of the 1906 crop is under experiment under S. P. I. No. 19969 and P. L. H. No. 3251. The 1907 seed is under experiment under S. P. I. No. 22946 and P. L. H. No. 3332. The present sample and S. P. I. No. 25537 are of the 1908 crop. (The so-called *Baltic* alfalfa.)" (*Brand.*)

25807. "(South Dakota No. 240.) Acclimatized *Turkestan* alfalfa, crop of 1908. This sample was grown from the same parent seed as No. 25805, South Dakota No. 164. This strain of Turkestan presents one of the most striking examples of acclimatization yet encountered. Seed of the original importation, S. P. I. No. 991, was grown at Highmore, S. Dak., from 1899 until 1906. Highmore seed was taken to Mitchell, S. Dak., in 1901, where it has since been grown. The present sample and S. P. I. No. 25607 are of the 1908 seed crop, grown at Mitchell. The 1906 seed crop, grown at Highmore, is under experiment under P. L. H. No. 3252." (*Brand.*)

25816. TACCA PINNATIFIDA Forst.

From Quilimane, Zambesia, Portuguese East Africa. Presented by Mr. O. W. Barrett, Director of Agriculture, Lourenço Marquez, Mozambique, Portuguese East Africa. Received July 31, 1909.

"Semicultivated plant having 3 to 5 Amorphophallus-like leaves from a cluster of smooth, thin-skinned, roundish corms and a corymbose cluster of greenish flowers on the summit of a naked, yellowish, erect stipe (some 3 to 4 feet high, about twice height of leaves). Corms edible. The natives use it in a variety of ways—like potatoes and dry it in the form of a coarse flour. Habitat, gardens (and vicinity) of natives in Zambesia district. Native name, *I'lide.*" (*Barrett.*)

Distribution.—Widely distributed in Africa, India, Australia, and the Pacific islands.

25817. BAROSMA CRENULATA (L.) Hook. **Buchu.**

From Cape Town, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Department of Agriculture. Received August 2, 1909.

"Buchu succeeds best if sown in time and treated in the same way as nursery transplants. It naturally grows in amongst large rocks, so that the roots go into the ground at the side of the rocks or large stones; this keeps the roots cool, and the ground holds moisture longer. Buchu stands here at 1,500 to 4,000 feet elevation." (*Lounsbury.*)

"This is a shrub about 3 feet high bearing short-petioled, opposite leaves, which vary in form from narrowly oval to lanceolate, with crenate margins and with the surface marked by pellucid oil glands. The leaves form a drug, official in many lands, in America under the name of *buchu leaves*, valued for their diaphoretic, diuretic, and tonic properties. They contain from 1 to 2 per cent of a volatile oil. The plant occurs uncultivated in the vicinity of Cape Town, South Africa." (*R. H. True.*)

25822 to 25831. **Gourd.**

From Nice, France. Presented by Hon. Dulany Hunter, consul-general. Received August 3, 1909.

Seeds of the following:

25822 to 25824. LAGENARIA VULGARIS Ser.

25822. Ornamental, spiral shaped, climbing.

25823. Ornamental, bottle shaped, climbing.

25824. Bottle shaped.

25822 to 25831—Continued.

25825. Luffa cylindrica (L.) Roemer.

Ornamental, sponge, climbing.

25826 to 25830. Lagenaria vulgaris Ser.

25826. Ornamental, stick shaped, grim.

25827. Ornamental, pointed end, climbing.

25828. Ornamental, siphon shaped, climbing.

25829. Ornamental, climbing. From Corsica, Bachouela.

25830. Ornamental.

25831. Cucurbita pepo L.

"The 'Festival des Gougourdons' is held here in the spring, and these seeds are from gourds which are exhibited there. The nurseryman states that the seeds should be planted in a flowerpot and not transferred until the plant is about to throw out a few leaves; that the soil should be well manured, but not too abundantly, as in that case the gourd does not become sufficiently dry to be used for holding liquids. When the plants are large enough they are tied to trellis work so they can be exposed to the sun. They need comparatively little water, and the fruit should be protected from heavy dews by being kept covered at night. The seeds are planted in the spring, and the fruit, which dries on the plant, is ready to be gathered by the end of September or early in October. The peasants at Cimiez produce pipes and other articles of odd shapes by wrapping parts of the gourd before it has ripened with soft pieces of cloth, and are thus enabled to bend them into the form they wish to produce. In this way the covered parts do not develop freely, and, remaining soft, can be bent into the desired shape." (*Hunter.*)

25841 to 25844. Allium cepa L. **Onion.**

From Teneriffe, Canary Islands. Presented by Mr. Solomon Berliner, American consul. Received August 5, 1909.

Seeds of the following:

25841. *Bermuda Red.*

25842. *Wildpret's Golden.*

25843. *Bermuda White.*

25844. *Crystal-War.*

25845. Macadamia ternifolia F. Muell.

From Wellington Point, Queensland, Australia. Presented by Mr. J. Pink. Received August 2, 1909.

For description, see S. P. I. No. 18382.

Distribution.—A small tree, native of the eastern part of Australia, being found in the valleys of the rivers in the southeastern part of Queensland, and in New South Wales.

25846. Olea foveolata E. Meyer.

From East London district, Cape Colony, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Department of Agriculture, who procured the seeds from Mr. Henry G. Flanagan, F. L. S., of "Prospect," Komgha district, for whom they were collected by a Mr. Oliver. Received August 9, 1909.

"The district where these seeds were collected has a warm, temperate climate with about 30 inches of rainfall, chiefly in the summer months." (*Lounsbury.*)

Distribution.—A tall shrub, native of the woods of the southern part of Africa.

25847. PROTEA GRANDIFLORA Thunb.

From Grahamstown, Cape Colony, South Africa. Presented by Mr. J. Medley Wood, director, Botanic Gardens. Received July 31, 1909.

A shrub or small tree, 3 to 10 feet high, with oblong, sessile, shining leaves, and large, white flower heads, which resemble a globe artichoke in appearance.

25848. SCHLEICHERA TRIJUGA Willd. **Kussum.**

From Dhamtari, Raipur, India. Presented by A. E. Lowrie, esq., Deputy Conservator of Forests. Received August 12, 1909.

"This seed ought to be sown in fairly rich sandy loam, in boxes, to begin with. When the young plants are about 9 inches high they should be planted out in a well-drained sandy soil." (*Lowrie.*)

"This Indian tree, known as the lac tree or Ceylon oak, is one of the sources of shellac. The wingless female of the lac insect (*Tachardia lacca* Kerr) with its piercing mouth parts punctures the bark of the young, tender twigs, from which the shellac flows down the stems and hardens. The seeds yield a fatty oil, the so-called 'Macassar' oil, which contains free hydrocyanic acid, as well as the glycerides of oleic, palmitic, and arachidic acids. The wood, which is much used, is hard and durable and takes a polish. The sapwood is white, the heartwood is reddish brown." (*R. H. True.*)

Distribution.—A large tree, native throughout central and southern India, and extending through the Malay Archipelago to the Philippines.

25849 to 25856. AVENA SATIVA L. **Oat.**

From Madrid, Spain. Presented by Mr. A. Ramirez, El Hogar Español. Received August 13, 1909.

Seeds of the following:

25849. Open, white, panicle.

25850. Large, white.

25851. Common.

25852. Large, white, panicle.

25853. Black, open, panicle.

25854. Black.

25855. Black oat with pendent panicle.

25856. Yellow.

25857. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Venice, Italy. Presented by Dr. Angelo Sullam, of Portotolle, Taglia di Po, Italy, through Mr. Haven Metcalf. Received August 14, 1909.

Black-Eye.

25858 to 25860.

From the Philippine Islands. Presented by Mr. William S. Lyon, Manila. Received August 16, 1909.

Plants of the following:

25858 and 25859. CALAMUS sp.

25858. From Batanes Islands.

25859. From Palawan Island.

"*Palasan*".

"All the good rattans I know are strictly equatorial and not to be thought of in any of our occidental possessions other than the Canal Zone. I have crossed

25858 to 25860—Continued.

25858 and 25859—Continued.

the Isthmus twice. The yellow clay still impresses my memory with its stickiness and with its similarity to the yellow clays of Mount Canlaon (Negros), where I think perhaps I have seen the most riotous growth of *Palasan*—our best rattan. As I remember it, the rainfall on the Isthmus is probably about 2,400 to 2,500 mm. (94 to 98 inches). If it is less than 2,000 mm. (about 79 inches), I think rattans would not do much, although at Perak the precipitation is less and they raise some good, long-jointed canes.

"For environment the rattans want jungle and plenty of it. My remembrance of the zone is that the hills were unbroken jungle. Calamus must have a thick mass of medium-sized vegetation to scramble over.

"There is a single feature of Calamus culture which differentiates it positively from every other sylvan product with which I am acquainted. It is (if there be any such thing) an exception to the law of selection. All are fit to survive under conditions where all other species except those fortuitously well placed would succumb. No amount of crowding or shading seems to choke off a young rattan. Its progress is tedious under adverse conditions, but it struggles up till it gets light and then nothing but the bolo or cutlass can hold it back. In planting practice, this gives it a supreme advantage over most plants. Further, it eliminates the bugbear and expense of jungle clearing, a matter which is to be heavily reckoned. I am not prepared to give a thesis on rattan culture, but close observation of its behavior in our smooth bamboo (cana boho), which makes a thicket impervious to any animal except a wild pig and which is voracious enough to choke out every other kind of vegetable life except Calamus, inspires me with exceptional credulity to believe it can be grown more nearly as a purely spontaneous crop than any economic product known, not excepting common timber trees.

"I am not advocating complete neglect; removal of a fallen limb or a rank herbaceous weed, or an occasional slash with a bolo, would probably accelerate growth, but it is not an essential facter to success. The best commercial rattans, both Calamus and Damonorpas, are spiny as hedgehogs and immune from the raids of even deer. Best of all, they are renascent from the butt, and the same land and same planting may be cut over in six or seven years for a second time. There are two very serious drawbacks to a very general adoption of rattan planting for profit. One, their shy fruiting habits and consequent scarcity of seed; the other, slow development.

"The fruits are eaten by birds, and seeds can only be obtained where they are concealed from the birds. All the species, I fancy, are, as seeds, of fugitive vitality. This is not only my own limited experience, but is evidently that of European seedsmen—those who are specialists in palm seeds, and who rarely offer them for sale. As most of the species until they reach the sprawling age are remarkably ornamental, far more so than most palms, I can only explain their absence from catalogues of tropical ornamentals upon these grounds.

"I can give you no idea of the time required to yield a crop. I only know that the crop is slow, very slow. The renewal crop is rapid. I have seen canes on cut-over lands which had been stripped four years before. I think in five or six years at most, and on poor lands, à second crop can be depended upon. A seedling crop, perhaps, in 10 years." (*Lyon.*)

25860. LIVISTONA WHITFORDII BECCARI.

"This is far more compact, bushy, and ornamental than *Livistona rotundifolia.*" (*Lyon.*)

Distribution.—A native of the province of Tayabas in the island of Luzon.

25861. MANGIFERA INDICA L. **Mango.**

From Trinidad, British West Indies. Presented by Mr. F. Evans, acting superintendent, Botanic Gardens. Received August 18, 1909.

Seeds.

Julie. See S. P. I. No. 21515 for previous introduction and description.

25862. CITRUS NOBILIS Lour.

From Saigon, Cochin China. Presented by Mr. Jacob E. Conner, American consul. Received August 14, 1909.

Seeds.

"A very fine, flat, green-skinned mandarin orange, a little larger than the ordinary ones of this type. The flesh is quite reddish in color, and the flavor is a combination of that of the ordinary flat and the round loose-skin oranges." (*Conner.*)

25863 to 25866.

From Nairobi, British East Africa. Presented by Mr. and Mrs. C. E. Akeley, Chicago, Ill., through Mr. Charles J. Brand. Received August 17, 1909.

Seeds of the following economic plants, grown by the Wakamba tribe of natives:

25863. PENNISETUM AMERICANUM (L.) SCHUM. **Pearl millet.**

Cat-tail millet, called by the Wakamba tribe *Mwee.*

25864. ELEUSINE CORACANA (L.) Gaertn. **Ragi millet.**

Wimbi.

25865. CAJAN INDICUM Spreng.

A species of bean. Mr. Akeley states that this is a bean of rapid growth which the natives use for wood.

25866. ZEA MAYS L. **Corn.**

A variety of Indian corn grown by the Wakamba tribe.

25867. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Merw, Russian Turkestan. Presented by Capt. M. L. Cummins, Sixteenth Infantry, U. S. Army, Fort Crook, Nebr. Received August 13, 1909.

"The melon is orange colored and not reddish inside, and in my opinion was the best I have ever eaten. The seeds came from a melon I had in Merw in the south-central part of Turkestan." (*Cummins.*)

25868 to 25869.

From Lourenço Marquez, Portuguese East Africa. Presented by Mr. O. W. Barrett, Director of Agriculture. Received August 14, 1909.

25868. (Undetermined.)

"(No. 29, June 28, 1909.) From Nhamacurra, Quilimane, Portuguese East Africa. Native name (Chizena) 'Mucuipile.' A forest plant growing in sandy soil. Rhizome (attaining a weight of several pounds), irregular in shape; starch content moderate. Height 2 to 4 feet." (*Barrett.*)

25869. GLADIOLUS sp.

"(No. 28, June 28, 1909.) From Nhamacurra, Quilimane, Portuguese East Africa. Native name (Chizena) 'Tumbanimasa.' A plant of the low moist lands of the Zambezi Valley. Flower pale yellow, medium size, opening nearly downward. Bulb, pale-brown coat, yellow inside. Height 2 to 3 feet." (*Barrett.*)

25870. STIZOLOBIUM sp.

From Barbados, British West Indies. Presented by Mr. Francis Watts, Commissioner of Agriculture, through Mr. John R. Bovell, superintendent. Received August 4, 1909.

"Bengal bean."

25871. TRIFOLIUM PRATENSE L. **Red clover.**

From Huntsville, Ala. Purchased from Mr. Clarendon Davis. Received August 6, 1909.

"Seed of red clover, which has proved disease resistant at Huntsville, where red clover usually suffers severely. This strain was developed from surviving plants." (*J. M. Westgate.*)

25874. PASSIFLORA EDULIS Sims. **Passion fruit.**

From Sydney, Australia. Presented by Van Dyk & Lindsay, importers, 209 Washington street, New York, N. Y. Received August 20, 1909.

See S. P. I. No. 12899 for description.

Distribution.—A native of Brazil, and cultivated in other tropical countries.

25876. PHASEOLUS LUNATUS L.

Presented by Mr. O. W. Barrett, Director of Agriculture, Lourenço Marquez, Portuguese East Africa. Received August 21, 1909.

"(No. 30, July 24, 1909.) A slender-stem, climbing, bean-like plant received from Mr. Henry Brown, of Mlanje, Nyasaland, and stated by him to have been brought from the Kongo basin. Grown at Lourenço Marquez. Flowers in short racemes, whitish." (*Barrett.*)

25879. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

From Lahore, Punjab, India. Presented by Mr. W. R. Mustoe, superintendent, Government Archæological Gardens. Received July 31, 1909.

See S. P. I. No. 24450 for description.

25880. PRUNUS TOMENTOSA Thunb.

From Ottawa, Canada. Presented by Mr. W. T. Macoun, horticulturist, Central Experimental Farm. Received at the Upper Mississippi Plant Introduction Garden, Ames, Iowa, July 29, 1909.

"(Ames Ac. No. 458, 1909.) 'This cherry appears to be hardier in fruit bud than any other cherry we have at the Experimental Farm, and as it makes good preserves and is fair eating I think it quite an acquisition.' (*Macoun.*) For more complete description, see Annual Report, W. T. Macoun, horticulturist, Central Experimental Farm, Ottawa, Canada. 1908 : 106." (*S. A. Beach.*)

Distribution.—A shrub or small tree, occurring in the northwestern part of India, northern China, Manchuria, and Japan.

25884 to 25887.

From Cochin China. Secured by Mr. Xavier Salomon, chief, Botanical Garden, Saigon, and presented by Mr. Jacob E. Conner, American consul. Received August 24, 1909.

25884 to 25887—Continued.

Plants of the following:

25884 to 25886. From Cape St. Jacques.

25884. Cinnamomum loureirii Nees.

"This species is supposed to be one of the most valuable sources c some of the best cinnamon that comes to our market." (*R. H. True.*)

Distribution.—A native of the mountains of Cochin China and of Japan

25885. Atalantia sp.

25886. Tetracronia cymosa Pierre.

Distribution.—A shrub or small tree, native of the mountains in th vicinity of Binh Dinh, French Indo-China.

25887. Garcinia mangostana L. **Mangosteen**

From Saigon. "This delicious fruit is about the size of a mandarin orange round and slightly flattened at each end, with a smooth, thick rind, rich red purple in color, with here and there a bright, hardened drop of the yellow juic which marks some injury to the rind when it was young. As these mangosteen are sold in the Dutch East Indies—heaped up on fruit baskets or made up int long, regular bunches, with thin strips of braided bamboo—they are as strikingly handsome as anything of the kind could well be, but it is only when th fruit is opened that its real beauty is seen. The rind is thick and tough, an in order to get at the pulp inside it requires a circular cut with a sharp knif to lift the top half off like a cap, exposing the white segments, five, six, or seve in number, lying loose in the cup. The cut surface of the rind is of a mos delicate pink color and is studded with small yellow points formed by the drops o exuding juice. As you lift out of this cup, one by one, the delicate segments which are the size and shape of those of a mandarin orange, the light-pink side of the cup and the veins of white and yellow embedded in it are visible. Th separate segments are between snow-white and ivory in color and are covere with a delicate network of fibers, and the side of each segment where it presse against its neighbor is translucent and slightly tinged with pale green. As on poises the dainty bit of snowy fruit on his fork and looks at the empty pin cup from which it has been taken, he hardly knows whether the delicate flavo or the beautiful coloring of the fruit pleases him the more, and he invariabl stops to admire the rapidly deepening color of the cut rind as it changes o exposure to the air from light pink to deep brown. The texture of the mangosteen pulp much resembles that of a well-ripened plum, only it is so delicat that it melts in your mouth like a bit of ice cream. The flavor is quite indescribably delicious and resembles nothing you know of, and yet reminds you with a long after-taste, of all sorts of creams and ices. There is nothing to ma the perfection of this fruit, unless it be that the juice from the rind forms a indelible stain on a white napkin. Even the seeds are often partly or wholly lacking, and, when present, are generally so thin and small that they are really no trouble to get rid of. Where cheap and abundant, as in Java, one eats these fruits by the half peck, and is never tired of them. They produce no feeling of satiety, such as the banana and the mango do, for there is little substance to the delicate pulp." (*David Fairchild.*)

25888 to 25890.

From India. Presented by Mrs. Effie Pyle Fisher, Igatpuri, through Mis Audrey Goss. Received August 25, 1909.

25888 to 25890—Continued.

Seeds of the following:

25888. FERONIA ELEPHANTUM Correa.

"This is the wood-apple of India and Ceylon, a deciduous tree with pinnate leaves, bearing a fruit about the size of an orange, but with a very thick, woody rind.

"The pulp of the fruit is acid and aromatic and is sometimes eaten by the natives of India; it is also used to prepare a jelly much resembling that made from black currants, but this jelly is said to have a very astringent taste.

"This plant is allied to the bael fruit of India, *Belou marmelos*, and is being grown to hybridize with that species, and also for trial as a stock upon which to graft it." (*W. T. Swingle.*)

Distribution.—A medium-sized tree, found in the sub-Himalayan forests. from the Ravi eastward, and throughout the greater part of the plains of India, being more frequent in the moist tracts of Bombay, Madras, Bengal, and Burma than in northern India.

25889. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

Both of the above are from the state gardens, Baroda.

25890. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

From Mr. George Hodson, florist and seedsman, Bangalore.

See S. P. I. No. 24450 for description of *Belou marmelos*.

25891 to 25893.

From Ootacamund, India. Presented by Rev. G. N. Thomssen, American Baptist Telugu Mission, Bapatia, South India. Received August 20, 1909.

Seeds of the following:

25891. RHODOMYRTUS TOMENTOSA (Ait.) Wight.

The Downy myrtle, or Hill gooseberry, is a handsome evergreen shrub, with broad glossy leaves, pink flowers larger than those of a peach and lasting for several weeks, and dark-purple berries about the size of a cherry and tasting like a raspberry. The fruits are eaten raw, and used for making jam and jelly. (*Adapted from Bailey.*)

Distribution.—An evergreen shrub, native of the southeastern part of Asia, extending from India through China, the Malay Archipelago, and the Philippines to Japan.

25892. PHYSALIS PERUVIANA L.

From plants of ten years' select cultivation of the South African Cape gooseberry in India.

Distribution.—A native of Peru and cultivated throughout the Tropics.

25893. (Unidentified.)

White straw flowers growing wild on the Nilgiris.

25894 to 25897.

From Simla, India. Presented by Mr. E. Cotes, Indian News Agency, through Mr. Frank N. Meyer. Received August 27, 1909.

Seeds of the following:

25894. AMYGDALUS PERSICA L. **Peach.**

25895. PRUNUS ARMENIACA L. **Apricot.**

25894 to 25897—Continued.

25896. PRUNUS PUDDUM Roxb. **Cherry**

Distribution.—A tree, native of the northern part of India, extending from the Indus to Sikkim, usually at an elevation of between 2,500 and 7,000 feet.

25897. PYRUS sp. **Pear**

"These seeds were collected from wild Himalayan fruit trees, growing at an elevation of 7,000 feet about Simla." (*Cotes.*)

25898 to 25901. VICIA FABA L. **Horse bean.**

From United Provinces, India. Presented by Mr. T. F. Main, Deputy Director of Agriculture, Poona, Bombay Presidency. Received August 27, 1909.

"The three last numbers seem to be of one variety collected from different villages, while the first is quite different." (*Main.*)

25902 and 25903. VICIA FABA L. **Horse bean.**

From Egypt. Presented by Mr. George P. Foaden, secretary, Khedivial Agricultural Society, Cairo. Received August 28, 1909.

Seeds of the following; notes by Mr. Foaden.

25902. *Saidi.* Planted in Upper Egypt under basin irrigation.

25903. *Beheri.* Planted in Lower Egypt under canal irrigation.

These are the same variety, but recognized by the cultivators as being cultivated under two different systems of irrigation.

25904 to 25907. VICIA FABA L. **Horse bean.**

From Friesland Province, Holland. Presented by Dr. M. Greshoff, Koloniaal Museum, Haarlem, Holland. Received August 6, 1909.

25908. MYRICA NAGI Thunb.

From Tangsi, China. Procured by Rev. Alexander Kennedy, at the request of Mr. Frank N. Meyer. Received August 21, 1909.

See S. P. I. Nos. 22977 and 22904 to 22906 for descriptions.

"These seeds are for stocks; better varieties are to be grafted on to them later. The plants are exceedingly hard to transplant. The trees thrive wherever the loquat does." (*Meyer.*)

25909. MIMUSOPS KAUKI L. **"Adam's-apple."**

From Lawang, Java. Presented by Mr. M. Buysman, Hortus tenggerensis. Received August 26, 1909.

A large tree, native of India, the Malay Archipelago, and Australia. The fruit resembles *Zizyphus jujuba* in flavor, and is edible. The wood is red, fine grained, and easy to work.

25910. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Entebbe, Uganda, British East Africa. Presented by the Botanical, Forestry, and Scientific Department. Received August 26, 1909.

Brown. There seem to be several varieties in this lot.

25911 and 25912.

From Lal Bagh, Bangalore, India. Presented by Mr. G. A. Gammie, Imperial Cotton Specialist, Kirkee, India, at the request of Mr. J. Mollison, Inspector-General of Agriculture in India. Received August 30, 1909.

25911 and 25912—Continued.

Seeds of the following:

25911. Feronia elephantum Correa. **Wood-apple.**

See No. 25888 for description.

25912. Belou marmelos (L.) W. F. Wight. **Bael.**

"The bael fruit is highly prized by natives of this country and is an article of food with them, especially in Upper India. A very nice cooling drink is made from its pulp in the hot season, also a nice jam is prepared out of it. The unripe and the ripe fruit and its rind, root, leaves, and flowers are used medicinally. Sherbet made from the ripe fruit is very valuable in cholera and bowel complaints." (*Gammie.*)

25913 to 25920.

From Hangchow, China. Presented by Rev. W. S. Sweet, Wayland Academy, Baptist Missionary Union, Eastern China Mission. Received August 2, 1909.

Seeds of the following; notes by Mr. Sweet.

25913 and 25914. Vicia faba L. **Broad bean.**

25913. Green. **25914.** Brown.

Vine 2 feet long. Used as human and animal food and also for firewood. Ripe from April to May.

25915. Dolichos lablab L. **Bonavist bean.**

White. Known as the crested bean; vine 4 to 6 feet; used as human food and for firewood; ripe in September.

25916. Phaseolus angularis (Willd.) W. F. Wight. **Adzuki bean.**

Red. Used for food; vine small and fine, 6 inches high; ripe in September.

25917. Pisum sativum L.

Tall vine; ripe from May to June; used for forage.

25918. Vigna sesquipedalis (L.) W. F. Wight.

Black. Tall vine.

25919 and 25920. Glycine hispida (Moench) Maxim. **Soy bean.**

25919. Yellow. Vine 1 foot high; ripe from November to December. The cheese made from this bean forms a large element of food here; if adapted to American taste a profitable business could be established in the States.

25920. Black. Ripe from June to August; used the same as No. 25919.

25921 to 25925.

From Leh, Ladakh, Kashmir, British India. Presented by Mr. Rassul Galwan. Received August 27, 1909.

Seeds of the following; notes by Mr. Galwan.

25921. Triticum aestivum L. **Wheat.**

Before this seed is sown the field is put under water till the ground is wet a half foot deep. Then wait ten to twenty days, till the ground is fairly dry and the seed can be sown. The ground must be neither too wet nor too dry. Before the seed is sown manure is spread about one-half inch thick over the ground. The first water is given when the wheat is about 2 inches high, the ground being soaked about one-half foot deep. After it becomes dry again a second watering is given. It is better to wait a little too long than to water too quickly.

25921 to 25925—Continued.

Up to the third watering care must be used, after that the wheat is strong and water can be given at any time it is dry. The more water given the better the crop.

25922. Hordeum sp. **Hull-less barley.**

The method of sowing this is the same as for wheat, the only difference being that this can be sown late, as it ripens in two to three months. Flour is made from it, but the bread is not as good as the bread made from wheat flour. Most people use it, therefore, as Suttoo, which is made as follows: First, wash the barley in cold water, after waiting one day put in the sunshine and let dry. Then fry in an iron pot until brown, then take to a mill and have it ground into flour, which is eaten with Ladaki tea; some eat it with water, some mix it with butter, sugar, and tea, for there is no need to cook it again. If hot things can not be had, it can be eaten with cold water.

25923. Vicia faba L. **Horse bean.**

Brownish black.

25924. Lathyrus sativus L.

This is sown with wheat. It can be sown in places a little cold, and there is no need to use any manure. The sowing methods are the same as those used in sowing wheat. The seed is sown about the 10th of May and ripens in about three months. At the sowing time the seed needs more moisture than wheat or it will not grow well.

25925. Pisum arvense L. **Field pea.**

This is sown in hot places, and does best in sandy soil. It is sown here about the 20th or the 25th of April, and ripens in about three months. The method of sowing is the same as that of wheat, except that no manure is put on the field. If manured the plants grow very large but without beans. The stalks are good to feed to animals. Before sowing, the ground should be wetter than when wheat is sown or the beans will not do well.

25926 and 25927.

From Igatpuri, India. Presented by Mrs. Effie Pyle Fisher, through Miss Audrey Goss. Received August 31, 1909.

Seeds of the following:

25926. Feronia elephantum Correa.

See No. 25888 for description.

25927. Anona reticulata L. **Custard-apple.**

See S. P. I. No. 5210 for description.

25928. Colchicum sp.

From Alpine heights of Geovjé Dagh, above Hassanbeyli, Amanus Mountains. Presented by Mrs. F. A. Shepard, Aintab, Turkey. Received August 19, 1909.

"A wild colchicum having large, pink, very showy blossoms in September. Fruit ripens in May." (*Shepard.*)

25929 to 25931. Cucumis melo L. **Muskmelon.**

From Columbia, Mo. Presented by Mr. G. C. Broadhead. Received August 21, 1909.

25929 to 25931—Continued.

Seeds of the following:

25929. 1903 crop.

25930. 1908 crop.

25931. 1909 crop.

"Between 1825 and 1835 the Rev. Albert Holladay, of Virginia, was Presbyterian missionary to Persia. He brought to America seeds of a cantaloupe. My father raised this melon in Virginia, and in 1836 brought seed to St. Charles County, Mo., where he raised it until his death in 1853. Relatives and friends have since raised it. I have for thirty years, also my brother William, living at Clayton, St. Louis County. The melon raised in Virginia and in Missouri for ten or twenty years was smaller and sweeter than that raised since. It seems the first was not much over 4 inches in diameter and good to the outer rind. The melon now is as much as 6 inches in diameter and has at least a one-half of an inch of rind. When ripe it pulls off easily and generally has a red gum at stem where it breaks. A good melon of this kind is still better than most others and we call it the 'Persian cantaloupe.'" (*Broadhead.*)

25932. MEDICAGO SATIVA L. **Alfalfa.**

From Aintab, Turkey. Presented by Mrs. F. A. Shepard. Received September 3, 1909.

"This seed was collected in the arid regions about Aintab, about 3,500 feet above the sea and 100 miles inland. There is scarcely any rain for five months in the year. The plant is not planted for pasturage, but grows upon wild lands, where sheep and goats browse." (*Shepard.*)

25934. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Robertson, Cape Colony, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Cape of Good Hope, Department of Agriculture, Cape Town, who procured the seeds from Mr. E. A. Visser, manager of the Experiment Station at Robertson. Received September 4, 1909.

Monkataan.

"Mr. Visser says this plant yielded melons at the rate of 75 tons an acre on the station grounds without any special care, and that the melons keep well and are excellent stock food. They weigh about 30 pounds each and have a firm, sweetish, somewhat tough pulp. The rind is mottled pale and dark green like common watermelons, as a rule, but is sometimes whitish in this strain. The seeds do not separate readily and no one seems to be trying to save more than he needs for himself, so there is little chance of buying a supply unless it is ordered a year ahead. Mr. Jack, who was director in the department here and is now farming, is trying in vain to get seed for 100 acres, which at least indicates that the merits of the crop appeal to him. Mr. Thornton, our agriculturist, tells me the plant has long grown to the west of Kuruman on the east side of the Kalihari desert. (The small Tsama melon sent to the United States grows on the west side.) He thinks it was probably cultivated there by natives in bygone days, but now it grows wild. Some years ago he got down seeds and had them planted near Graaff Reinet. Farmers of the district soon appreciated the value of the melon and took to its cultivation as a stock food. It is said on good authority to have yielded as high as 150 tons an acre around there, the ground becoming almost obscured by the fruits. The strain introduced to the Robertson station is from Graaff Reinet way, not direct from the desert, and Thornton thinks there is a possibility that it is not quite true to type; but if it is not, it is an improvement on the original he thinks.

25934—Continued.

"It seems to me that this or other of the South African melons should be more wort cultivating in arid parts of the West than the thornless prickly pear. Of course th melons want water, but much of what they get they store away for months." (*Lounsbury.*)

"One of our experimenters of the *Monketaan* melon has just reported that the retur per acre of melons amounted to 103 tons, and it was found that on an average the were two melons to every square yard of land. This melon, according to the analysi we have already had made, is high in feeding value and promises to take a leadin part in some of our stock districts." (*Extract from letter of Mr. R. W. Thornton, government agriculturist, Cape Town Department of Agriculture, August 24, 1909.*)

25935. VICIA VILLOSA Roth. **Hairy vetch.**

From Moscow, Russia. Purchased from Immer & Son, through Prof. N. E. Hansen, Agricultural Experiment Station, Brookings, S. Dak., while traveling as an agricultural explorer for this Department. Received September 7, 1909.

25936. ROSA sp. **Rose.**

From Ogden, Utah. Presented by Miss Pearle Cramer, United States Department of Agriculture, Forest Service. Received September 7, 1909.

Yellow. "This rose, so far as I have been able to ascertain, is native only to Utah where it grows in great profusion." (*Cramer.*)

25937. ORYZA SATIVA L. **Rice.**

From Tsangsheng, Kwangtung Province, near Canton, China. Presented by Mr. Stuart J. Fuller, American vice consul-general-in-charge, Hongkong, for whom it was procured by Mr. Leo Bergholz, American consul-general at Canton. Received September 9, 1909.

"*Szemiu*, the translation of which means 'Best quality refined.' The Chinese rice merchant states that the exportation of this rice in any quantity or in samples is forbidden by the Chinese Government." (*Amos P. Wilder, American consul-general, Hongkong, China.*)

25938 to 25940. MANGIFERA INDICA L. **Mango.**

From Philippine Islands. Procured by Mr. William S. Lyon, Gardens of Nagtajan, Manila, P. I. Received September 8, 1909.

Seeds of the following standard varieties:

25938. *Carabao.*

See S. P. I. Nos. 24927 and 25659 for previous introductions.

25939. *Pico.*

See S. P. I. No. 24170 for previous introduction.

25940. *Pahutan.* "From my viewpoint this is the best, *not* horticulturally, other than being a vigorous grower, early fruiter, and enormously prolific. Its very serious defects—small size, scanty flesh, and excessively large seed—are from my point of view fully offset by a smoothness, sweetness, juiciness, and flavor unapproached by any other. I have eaten the famous *Alphonso* mango in Calcutta and do not consider it ace high with *pahutan*. *Pahutan* further has a very thick rind. This, while still further diminishing its scanty flesh, probably adds to its shipping qualities." (*Lyon.*)

25941. ELEPHANTORRHIZA ELEPHANTINA (Burch.) Skeels.

Acacia elephantina Burch., Trav., vol. 2, p. 236. 1824.

Acacia elephantorrhiza (Burch.) D. C., Prod., vol. 2, p. 457. 1825.

Elephantorrhiza burchellii Benth., Hook Journ. Bot., vol. 4, p. 344. 1842.

Although Burchell is given as the authority in De Candolle's Prodromus for the specific name *elephantorrhiza*, the name he really used and under which he gave an excellent botanical diagnosis is that here recognized.

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, director, Transvaal Department of Agriculture. Received September 10, 1909.

Seeds.

"All grazing animals, wild and domestic, are exceeding fond of this plant. It has long, succulent roots and an underground stem. It does not shoot until rather late in the summer, seldom before December, and its stems are killed again by the first frosts of May. The seed-pods are still green when the frost comes, and the seeds not ripe, but they are so well protected by the strong, leatherlike pod, that the frost can not hurt them, and they ripen in the pod long after the stem that bore them has been killed by the frost. The roots are used for tanning leather." (*Mrs. Barber, in Harvey, Flora Capensis, vol. 2, p. 277.*)

Distribution.—South Africa. Common in grassy places between the Klipplaat and Zwartkey rivers in Cape Colony. It occurs also in the Cradock and Queenstown districts in Cape Colony, and is reported from the "Zooloo Country." Originally described from near "Klaawater" in the southern part of Orange River Colony.

25942. BERBERIS SANGUINEA Franch.

From Nancy, France. Purchased from V. Lemoine & Sons. Received September 14, 1909.

"This is a little-known species from China and appears to be closely allied to *Berberis nepalensis*. The blooms are said to be deeper orange-red than any other species. These plants are imported for hybridizing purposes." (*W. Van Fleet.*)

Distribution.—A native of dry stream beds in the province of Szechwan, China.

25950 to 25953. VICIA FABA L.

From Valencia, Spain. Presented by Mr. Charles S. Winans, American consul. Received September 8, 1909.

Seeds of each of the following:

25950 to 25952. **Broad bean.**

25950. *Caliente.* Light brown.

25951. *Panesca.* Purplish brown.

25952. *Murciana.* Dark purple.

25953. **Horse bean.**

Favon. Purplish black.

25956 and 25957.

From Amanus Mountains, Turkey in Asia. Presented by Mrs. F. D. Shepard, Adana. Received September 9, 1909.

Seeds of each of the following:

25956. AVENA SATIVA L. **Oat.**

25957. VICIA ERVILIA (L.) Willd. **Bitter vetch.**

25959 to 25962. ZEA MAYS L. **Corn.**

From Central Soledad, Cienfuegos, Cuba. Presented by Mr. Robert M. Grey, Harvard Botanical Experiment Station. Received September 21, 1909.

Seeds of the following; notes by Mr. Grey.

25959. *Harvard selected flint.* This is our surest cropper, best keeper, and, being free from surface starch, less subject to attack from weevils and ants.

25960. *Selected white flint Cuban.* This is used as a sweet or table corn, is early, and a small-cob variety.

25961. *Hybrid purple cob (Cuban dent × Cuban flint).*

25962. *Cuban dent.*

These two last are the varieties commonly cultivated here and are very productive.

The above have been under selection for six years. The husk of all closes tight at the apex, a great prevention and safeguard against insects.

25963. VICIA FABA L. **Horse bean.**

From Magyaróvár, Hungary. Presented by The Plant Culture Experiment Station, requested from Prof. A. Cserhati. Received September 22, 1909.

"These seeds are planted in the spring and mature in about one hundred days. The plants grow from 35 to 40 centimeters high. The beans are ground up and make a very nutritive food for stock. The fodder is of hardly any value." (*Gyárfás.*)

25964. GOSSYPIUM HIRSUTUM L. **Cotton.**

From Nyasaland Protectorate, British Central Africa. Presented by Mr. J. Stewart J. McCall, Director of Agriculture, Zomba. Received September 27, 1909.

"Seed of Upland cotton which received the first prize at the recent show at Blantyre. I think you will consider it a very high-class hirsutum cotton, and it is very gratifying as we received 6d. to 7d. per pound for it at the Manchester market." (*McCall.*)

25965. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received September 10, 1909.

"Kafir bean." This lot apparently contains several different varieties.

26047. GARCINIA MANGOSTANA L. **Mangosteen.**

From Port of Spain, Trinidad, British West Indies. Presented by Mr. F. Evans, botanical department, Department of Agriculture. Received fall of 1909.

Seeds. See No. 25887 for description.

"The mangosteen will be an unusually good shipper, as tropical fruits go. The small crate of fruits from which these seeds were taken, shipped by Mr. Evans on the 28th of September, was delayed for more than a week in New York and reached Washington on the 19th of October. Even after holding these fruits for five days after arrival in Washington—i. e., twenty-six days from the time they were picked—they were still in an edible condition, although naturally they had lost a good deal of their delicacy and the pulp had begun to adhere to the thick rind. One remarkable feature about these fruits lies in the fact that as they decay the rind hardens until it becomes almost as hard as a rock. I believe it may not be necessary to crate these in shipment on this account. A single rotten fruit may not infect others, as in the case of mangos or other soft-skinned fruits; in fact, as tropical fruits go, it seems to be an ideal shipper." (*David Fairchild.*)

PUBLICATION OF NEW NAMES.

It has been thought desirable to call attention to the new names which it is occasionally found necessary to publish in the inventory by giving a list of such names as they occur. This list will therefore appear in future issues on the page of the inventory preceding the index.

The following name is published in this issue:

25941. Elephantorrhiza elephantina (Burch.) Skeels.

The names given below have been published in preceding issues of the inventory:

21750. Albizzia adianthifolia (Schum.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 12.

21797. Sesban bispinosa (Jacq.) Steud.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 15.

21820. Xiphagrostis condensatus (Hack.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

The correct name for the above is *Miscanthus condensatus* Hack.; the genus Xiphagrostis [Contributions from the U. S. National Herbarium, vol. 9, 1905, pp. 399–400] having been based on a misconception of the type of Miscanthus as established by Andersson in 1856. That author indicated in a note that he did not consider the first species, *M. capensis*, as typical of the genus, and the second species, *M. japonicus*, should accordingly be recognized as the type. The usual application of the generic name Miscanthus therefore remains unchanged.

21824. Phaseolus angularis (Willd.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

21893. Chrysanthemum stipulaceum (Moench) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 21.

22349. Phragmites vulgaris longivalvis (Steud.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 46.

22390. Garcinia tinctoria (DC.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 50.

22813. PINELLIA COCHINCHINENSE (Blume) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 35.

22957. BELOU MARMELOS (L.) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 48.

23219. FIRMIANA SIMPLEX (L.) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 67.

23428. MYRCIARIA EDULIS (Vell.) Skeels.

Bulletin 148 (Inventory No. 16), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 14.

23472. PHYLLANTHUS ACIDA (L.) Skeels.

Bulletin 148 (Inventory No. 16), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

23897. CRYPTOCARYA RUBRA (Mol.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 15.

23963. BRASSICA PEKINENSIS (Lour.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 21.

24087. CALLISTEMMA CHINENSIS (L.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 27.

24591. BELOU GLUTINOSA (Blanco) Skeels.

Bulletin 162 (Inventory No. 18), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 26.

24631. GOURLIEA SPINOSA (Mol.) Skeels.

Bulletin 162 (Inventory No. 18), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 31.

25546. CLAUCENA LANSIUM (Lour.) Skeels.

Bulletin 168 (Inventory No. 19), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 31.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 177.

B. T. GALLOWAY, *Chief of Bureau.*

A PROTECTED STOCK RANGE IN ARIZONA.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 11, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 177 of the series of this Bureau a manuscript entitled "A Protected Stock Range in Arizona," by Dr. David Griffiths. This paper has been submitted for publication by Prof. W. J. Spillman, Agriculturist in Charge of the Office of Farm Management.

This is the second report upon range investigations in the Santa Rita National Forest in cooperation with the University of Arizona. It portrays the effects of proper protection of the native pastures of the region and shows that results are much more certain of accomplishment by proper management than by attempting reseeding operations.

Respectfully,

A. F. Woods,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—547.

A PROTECTED STOCK RANGE IN ARIZONA.

INTRODUCTION.

This report is one of progress simply and is necessarily incomplete, the details being purposely omitted. Many essential facts are also left out, because they have been included in a previous bulletin [a] of the series of the Bureau of Plant Industry.

The investigations really date from 1903, when a tract of land 49.2 square miles in area upon the Coronado National Forest was closed to grazing by arrangement with the Forest Service and in cooperation with the agricultural experiment station of the University of Arizona. Since that time another small tract of nearly a section has been inclosed and cooperative arrangements entered into with four ranchers contiguous to the south and east line of the large tract whereby the investigations will be considerably benefited in extent of territory, diversity of conditions, and interpretation of results by practical range operators. The map, figure 1, shows the area covered and the locations of the different pastures. A record of the operation of these areas under different systems of management during the next few years ought to throw important light upon the value of the proper handling of these semidesert lands.

EARLY HISTORY OF THE INCLOSED AREA.

Before the inclosure of this area it was open range, and large herds have fed here for years. The cattle usually come over in the fall from the other side of the mountains and remain until the April round-ups. In the upper portion of the field there was once a ranch of one of the largest cattle companies of southern Arizona, which has always been heavily grazed, but much heavier in times past than during the last few years before the inclosure was made. All in all, it may be said that heavy pasturing was the rule here for many years previous to that time. (Compare the two illustrations shown in Plate I.) A portion of the area farthest from water, mostly on the edge of the perennial-grass area, was grazed only during the wet season when it could be reache by stock. It was therefore in much better condition than that lyin closer to the mountains, where water was more convenient.

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[a] Bulletin 67, Bureau of Plant Industry, U. S. Dept. of Agriculture, entitled "Range Investigations in Arizona." 1904.

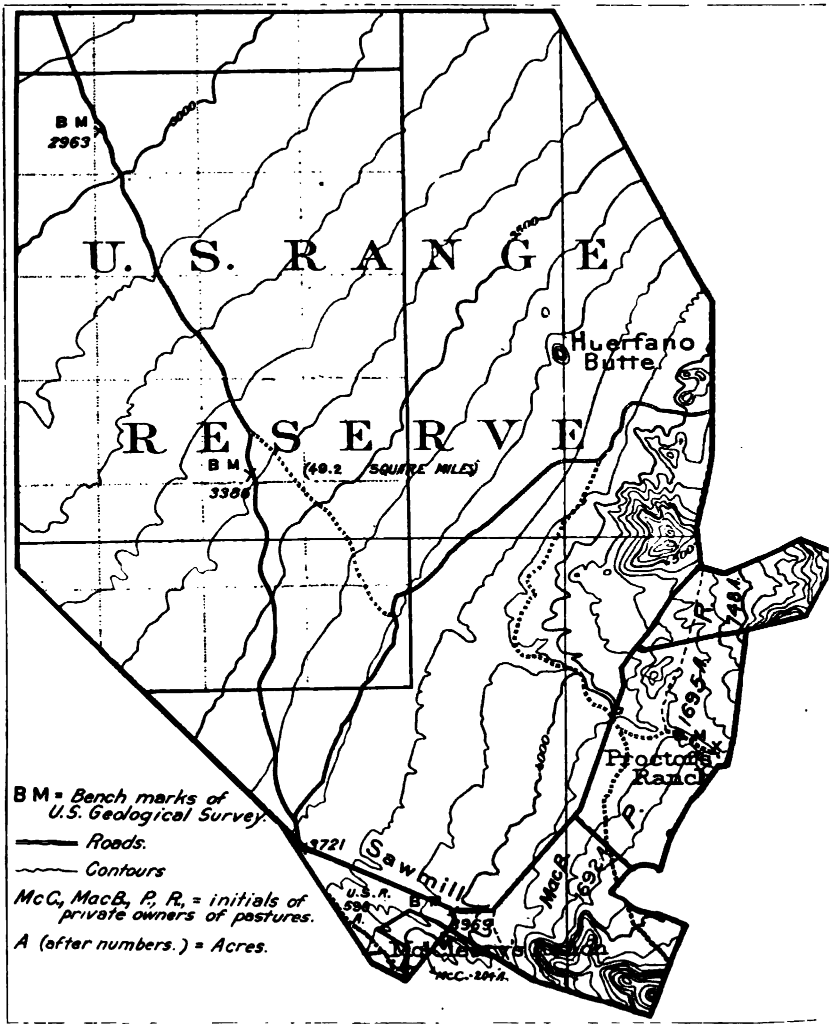

FIG. 1.—Map of fenced pastures in the Coronado National Forest, compiled from maps by the Unit States Geological Survey, the Forest Service, and the Bureau of Plant Industry.

HISTORY OF THE AREA SINCE 1903.

The large field was inclosed in June, 1903. By the first of the yea 1908 the pastures marked upon the map (fig. 1) *P.*, *R.*, and *MacB* were sufficiently inclosed to permit the control of stock in them, an the inclosures were completed later. These areas were inclosed b ranchers in cooperation with the Department of Agriculture. The 204-acre pasture was inclosed years ago and has been moderatel

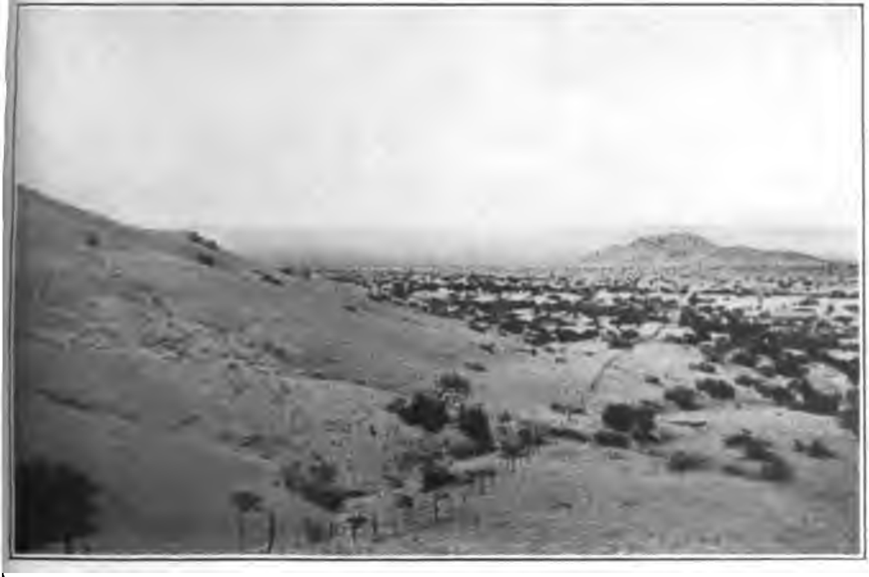

FIG. 1.—RANGE LAND INSIDE AND OUTSIDE OF THE FENCED AREA IN JUNE, 1903.

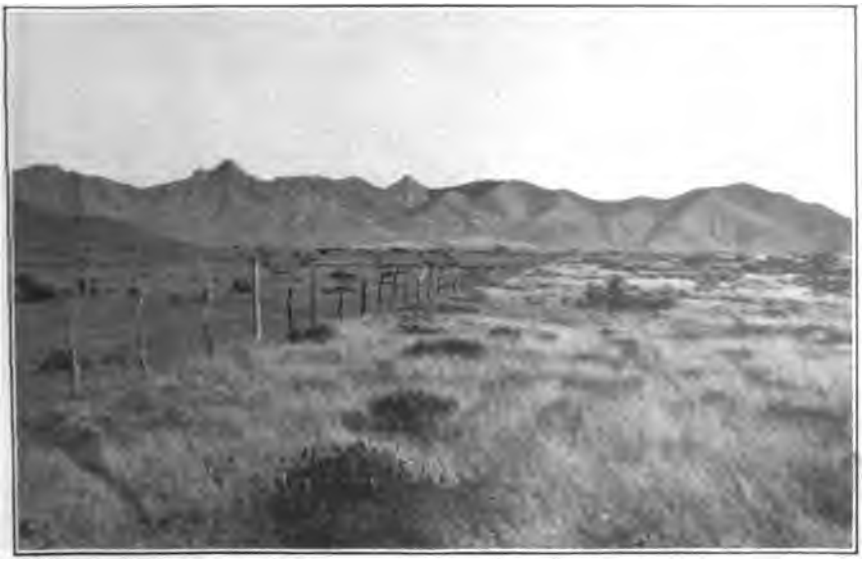

FIG. 2.—RANGE LAND INSIDE AND OUTSIDE OF THE FENCE LINE IN APRIL, 1905.

PASTURES SHOWING IMPROVEMENT DUE TO TWO YEARS' PROTECTION BY FENCING.

stocked ever since. A large part is in heavy brush, and consequently not as productive as it would otherwise be. A few head of stock have been allowed in the 590-acre pasture since it was fenced, but the large area has had no stock upon it since it was inclosed except an occasional stray. The pastures *P.*, *R.*, and *MacB.* have been handled by their owners very much as their judgments dictated, a record being kept in all cases of just what treatment each pasture received.

SURFACE COVERING.

The accumulation of dead herbage upon the surface of the soil of the area takes place very slowly. When the growth first dries up in the fall after a good rainy season there is an accumulation of, perhaps, a thousand pounds of dry matter to the acre. This is enough to make a big fire if ignited shortly after the dry season sets in. If left upon the ground for one year in this climate, however, it largely disappears, from the action of wind and weather, so that the accumulation, while surely taking place from year to year, is very slow. In this inclosure after six years of protection there is in no portion of it a complete ground cover during the entire year. There is, it is true, at the close of the rainy season grass two feet or more high in some places, but, as is characteristic of desert vegetation, it is thin and largely disappears before the next season. In the lower portion of the field, where the annual grasses predominate, the accumulation is next to nothing, but it gradually increases toward the higher level and is most abundant in the extreme southern portion of the inclosure. (See Pl. IV, fig. 2.) The occurrence of a dry year largely obliterates any cover that may have accumulated during the previous season. In short, even after six years of protection there is now in the lower portion of the field practically no ground cover, and in all probability there never has been any. In the upper portion, while the growth increases under protection, there is yet only about half a cover on the ground during the entire year. In the upper country, at an altitude of 3,500 feet and upward, a large accumulation of dead herbage can be kept upon the ground under a good system of management, as is being done in some private and cooperative pastures in the region now, but below this altitude the ground cover is not a factor of much consequence, for the grasses are mostly annual. Of course, upon the swales which receive flood waters the galleta and other grasses make a large growth and protect the surface, but such areas do not occur in the inclosures here described.

It will be seen that the matter of growth is one of distribution of moisture, which is influenced by altitude. As stated elsewhere, the rainfall quoted in this paper is taken in the 204-acre pasture. This point probably receives more rainfall than any portion of the large inclosure, the precipitation decreasing gradually northward until one reaches a point where it is too light to support the perennial grasses. However, a few miles to the northeast of the field there is an area of lower ground where hay has frequently been cut, but this is due to the spread and accumulation of flood waters over the surface. It is more than probable that the rainfall where the gauge is located is from 1½ times to twice that in the lower (northern) portion of the field, which represents more closely the conditions obtaining around Tucson. Besides, the distribution of rainfall is much better in the upper portion of the inclosure, more frequent rains occurring than in the low altitudes.

CONDITIONS INSIDE AND OUTSIDE OF THE FENCED AREA.

Upon the north and the west sides of the field there is practically no difference between the inside and the outside of the inclosure. There are two reasons for this. The north and northwest portions are the least productive of the field, and in this neighborhood water is a long way off, so that the stock graze here very little. Indeed, there have been but few cattle in the vicinity of the fence from the private pastures to the northwest corner for two years. (See map, fig. 1.) As a consequence, upon the southwest side a small crop of hay was cut on the outside of the fence last year.

On the east side, outside of the inclosure, the pasture is very short, having been grazed for years by horses and sheep. The conditions here are most instructive. The year 1908 was a favorable one and, consequently, in spite of the heavy grazing, some of the valuable perennial grama grasses matured seed to a much greater extent than in former years. This illustrates the extreme persistency of these grasses. They may be greatly abused even in this easily eroded and parched region, but when a favorable season occurs they again make their appearance and will, if husbanded for a few years, regain their supremacy. There is no doubt that there was at least ten times as much growth of these valuable perennials in 1908 as there had been for the previous three or four years. On the whole, there was in 1908 a fairly good crop of vegetation on this badly denuded region tributary to Helvetia, but it consisted in largest measure of the six-weeks' grasses, which are the poorest in the region.

From McCleary's south gate to Helvetia the area next to the government fence is now entirely protected by private holdings. (See map, fig. 1.) Although some of these have been only partially protected from the very excessive grazing of the previous years for somewhat less than twelve months, there is a phenomenal difference between them and the outside range. In one instance an inclosure of nine months' duration can be recognized for a distance of six or more miles even though the area has been grazed moderately all the time.

NATURAL RESEEDING.

Nature is normally profligate in her seed supply. It seems at times, especially with desert plants, that germination will insure seed production; in other words, many plants which have sufficient moisture for germination seldom fail to produce some seed. Indeed, in an average season the annual plants of the desert produce enough seed to restock the same land and insure as large a subsequent crop as the sterile soils can maintain. A small percentage of the more common plants grow each year and in turn produce seed. As an example we might cite *Bouteloua aristidoides*. A season is seldom so dry that some of this grass will not grow and produce seed. The plants may be a foot high and yield very little seed, or the spikes in a favorable year may equal the entire length of the plant in an unfavorable one.

It is different, however, with the perennial grasses. A season which produces an abundance of seed may be followed by one unsuited to the growth of seedlings, and consequently the crop of seed, although it falls to the ground, may be largely lost. Since the Department's operations in the Santa Rita Mountains were begun there have been but two years favorable for reproduction. The season of 1907, although not so prolific as the subsequent one, produced an abundance of seed of *Bouteloua rothrockii* and *Bouteloua bromoides*, two of the most important grasses in this region. This was followed by a very favorable season in 1908. There was consequently an exceptionally good growth of seedlings that season. It is quite possible that the seedlings of these two grasses over the entire areas in which they are peculiarly characteristic would average from four to six to the square foot. These seedling plants were all well established and in thrifty, vigorous growing condition on October 1, 1908.

The condition of these seedlings the next season was not only of scientific interest but of exceeding economic importance. If they all grew to maturity and produced plants the next year as vigorous and large as those that grew on the same area the yield ought to be increased 50 per cent, other conditions being equal. This condition, of course, was beyond the range of probability, because such a yield would be beyond the capacity of these desert lands to produce. As a matter of fact it is doubtful whether the yield of perennials in the upper portion of the field was much greater in 1909 than in 1908, in spite of the large number of seedlings of 1908. Natural selective influences work to thin this stand to the typical thin, scattering, bunchy condition best adapted to maximum production upon arid lands, a principle becoming better and better recognized in the growing of farm crops with small amounts of rainfall. Thin seeding is now recognized to be best under such conditions. The difference between a good crop and a small one in the perennial-grass region o these deserts is not so much due to a larger number of plants as to larger plants or clumps of plants.

Our experience upon this inclosed tract seems to indicate that the natural restocking of the perennial range by new plants takes place at irregular intervals. The ratio of increase may bear no relation to the quantity of seed produced the previous year. In other words, a favorable season for seed germination following a poor season of seed production may develop vastly more seedlings than one of poor distribution of moisture following an abundant seed production. Since this area was fenced, there has been but one season when the production of perennial-grass seedlings failed almost entirely. On the other hand, there have been but two years in five when a decided increase was noticed, the increase in 1907–8 being enormously greater than any of the others.

ARTIFICIAL RESEEDING.

Many attempts have been made to introduce forage plants in this section, both in the large inclosure and upon the holdings of private individuals in the vicinity. There is but one species that has given any beneficial results. Alfilerilla (*Eurodium cicutarium*) has been tried several times and in various situations. In brushy pastures in the upper foothills it has produced a thick mat of herbage some years, while in others the growth has been poor. All in all it has done well in patches, but only in the most favorable situations, in rather loose soil, where the grazing has been quite heavy and there is open mesquite brush. This plant grows in the winter; consequently, the shade furnished by the mesquite is at a minimum when the plant grows. It has taken four or five years for it to become well established.

In the open foothills, where the best pasture is found, the growth of this plant has been of no consequence. It has been started in several places, and indeed there were patches of it to be found in several situations when the field was inclosed, but even these have not spread. In short, the plant does not appear to be able in this situation to compete with native vegetation when the latter is not grazed. In one locality, along the fence line, there has been for years a patch of a few acres established no one knows how, but probably by sheep. This has been watched with interest, but the growth of alfilerilla has been less under protection than in the open where the land was heavily grazed.

In all, some two hundred species of forage plants have been planted in this inclosure. Many native species were tried, but the vast majority used were of foreign importation. At one time the Office of Forage-Plant Investigations of the Bureau of Plant Industry furnished more than one hundred varieties for testing. In some cases the seed was covered and in others scattered without any further attention. The plan has been, whenever the quantity of seed permitted, to sow one-half in the fall and one-half in the early summer. In some cases the ground was worked up sufficiently to kill about half of the original vegetation.

The net economic result of all this foreign introduction has been practically nil. It is not necessary to go into details regarding these plantings, even to the extent of publishing a list of the seeds planted. Most of the species, in our experience, have never come up, and the few things that did make any growth usually died before seed was produced.

In 1906 large quantities of wild oats (*Avena fatua* and *A. barbata*) were planted in June. Germination was very good, and by the 1st of January, 1907, the plats were promising, but the plants soon dried up, never getting over about 2 inches high. The seed did not germinate until the winter rains set in. The previous year seed of bur clover (*Medicago denticulata*) from California was sown in large quantity and well covered. It started beautifully, but dried up and died in April when about 2 inches high, with no seed production.

Tucolote (*Bromus maximus*) matured a few plants from one of the several seedings made, but seems to have disappeared entirely. This is one of the most aggressive species upon the California ranges. It might not be a detriment here, for it is a winter annual, and therefore would come in competition with only weedy spring plants and would probably have no effect on the crop of forage which comes in summer.

Results in reseeding, so far as these experiments have progressed, can be secured much more satisfactorily by the use of seed of native forage plants than by the use of the seed of plants from foreign countries. But even with these the results are not commensurate with the expense of getting the seed and growing it. Much more satisfactory results have thus far been obtained by husbanding the native vegetation and grazing well within the capacity of the land to maintain stock. In short, so far as information gained from experiments thus far conducted is concerned, these lands, although very badly overgrazed, will return approximately to their original productivity under complete protection in about three average years. Complete protection, however, is not necessary, though of course it will take longer to restore lands to their full productivity when grazing is practiced.

These remarks apply only to the plants already tried, the majority of which had some claim to succeeding in dry situations. It is not impossible that some foreign plants may yet be found which will succeed here, and all which have any chance of success should be tried. But meantime proper handling of the native vegetation is urged—a system of grazing which it is well within the capacity of the land to maintain.

A number of native grasses have been caused to spread successfully by gathering the seed in advantageous localities and simply scattering it where the ground was badly denuded. Better results have been obtained when seeding was done the last of June or the first of July. When sown in autumn the ants pick up too many of the seeds. Beneficial results have been secured in this way by the use of the seed of *Andropogon saccharoides*, *Bouteloua vestita*, and *B. rothrockii*. Less positive results have been secured by the use of native seed of *Bouteloua curtipendula* and *Leptochloa dubia*. Indifferent results have been secured with *Bouteloua oligostachya*. It should be noted that the last is a very important grass on the east side of the Santa Rita Mountains, but, so far as the writer knows, it does not occur on the northwest side of the divide except in one small, well-established patch. The origin of this is not certain, but it is believed that it was established by seeding done in 1901. It is a beautiful, vigorous growth in a place which was badly denuded at that time.

The above illustrations of the successful use of native species are important and interesting, but they have no applicability to open-range conditions. However, where the land is under fence and seed can be secured in the vicinity without too much expense, improvements can be made in very badly trampled areas. When the roots of the native growth are not completely destroyed, it is questionable whether in such situations as this recuperation would not occur fully as rapidly by proper protection from overgrazing without the use of seed as with it.

It must be remembered that the chances of failure of seed in such a region are very great. It is not necessary to discuss at length the contributing causes. They are many. The most important are the irregularity and the uncertainty of the rainfall.

TEMPORARY CHANGES IN VEGETATION.

The most striking changes in vegetation are those which take place from year to year in annual plants, and this is always noticeable in any region where the annual vegetation predominates. As a concrete example, the growth upon one of the inclosures in 1907 may be compared with that of 1908. In a badly denuded portion of one of the fields a blue-flowered, aster-like composite (*Machalranthera* sp.) was decidedly conspicuous. It was estimated that in 1907 one could have cut with a mower at least 500 pounds of dry matter to the acre from a large area. In 1908 one would have been obliged to cut not less than 30 acres to secure 500 pounds. The only place that the plant grew the second year was along washes and rivulets, which,

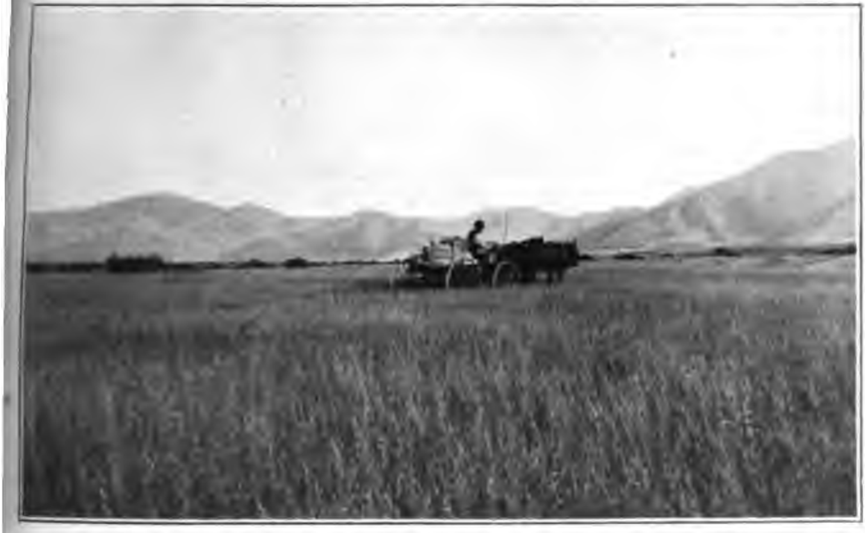

FIG. 1.—FIELD OF BOUTELOUA ROTHROCKII IN A GOOD SEASON, 1908.

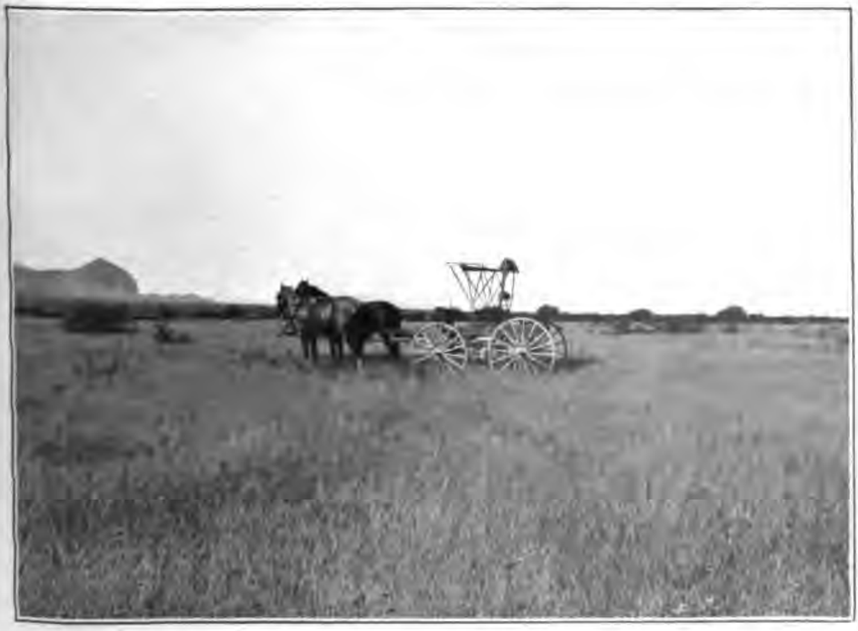

FIG. 2.—FIELD OF BOUTELOUA ROTHROCKII IN A POOR SEASON, 1907.

COMPARATIVE GROWTH OF GRASS ON RANGE LANDS IN A GOOD AND A POOR SEASON.

however, never had water except during a rain. In 1908 this aster-like plant was supplanted by *Bouteloua aristidoides*, *Aristida bromoides*, and other weedy annual grasses. Besides these, there was a thin and very irregular growth of such valuable perennials as *Bouteloua rothrockii*, *Bouteloua bromoides*, *Leptochloa dubia*, and *Bouteloua vestita*. This area was in the 590-acre inclosure (marked U. S. R. on the map, fig. 1). The changes were more noticeable than in the large field because the small field was more completely denuded of its vegetation. It is quite probable that the productive capacity of the small field is much below the average of similar portions of the other field.

But such differences in vegetation, comparing one year with another, are very striking. There has not been one year in ten when there was such a crop of *Plantago fastigiata* throughout the region (see Pl. V, fig. 2) as in the spring of 1901. In the large field, even with similar rainfall, there occurs an ascendency of one plant one year and of another plant another year, and this is more especially true of the growth of the spring season, which is more truly annual. One year the Arizona lupine (*Lupinus arizonicus*) gives its characteristic color to the landscape. Another year may witness the same with reference to *Orthocarpus purpurascens palmeri*. *Lotus humistratus* may be the abundant species another year, and *Pectocarya linearis* another. In the upper portion of the large inclosure at the present time there is a good stand of perennial grasses. These grow in the relatively humid summer season. During the summer there is a very sparse growth of annuals. In the spring, however, this region which grows grass in summer has its complement of annuals, and the relative abundance of the species varies about the same as it does on the lower portion of the field, where the perennials do not occur.

So far as known, no one has ever offered an explanation for these yearly variations of annual vegetation. The change in the aspect and balance of the species occurs in the annuals only. There has been no change, so far as anyone can see, in the areas of *Bouteloua rothrockii*, *Bouteloua bromoides*, *Aristida divaricata*, or *Aristida californica* in the large inclosure since the beginning, excepting a gradual thickening up of the respective species and a consequent shutting out of the annuals. (See Pls. II and III.)

PERMANENT CHANGES IN VEGETATION.

The rancher in this region is only half wrong when he asserts, as he commonly does, that the six-weeks' weedy and low-quality grasses have recently taken the range and driven out what he calls "root grasses," or the more valuable perennials. It is only the last portion of the statement that is false. The perennials, or more valuable species, have, it is true, disappeared, but they were not driven out by annuals, but, on the contrary, by the rancher's cattle.

The annual grasses of this region, such as *Bouteloua aristidoides* and *Aristida bromoides*, are not much relished by stock. They have harsh, hard glumes which penetrate the flesh. They dry up early, leaving but little substance, and, more than all this, they pull up by the roots when grazed and carry with them sand and dirt. They are therefore not eaten while the perennials are available. When the latter become impoverished by excessive grazing the former flourish. The ranges have therefore at present a larger proportion of weedy annuals, not because the latter are more aggressive, but because the former have been impoverished and to a large extent in many sections killed out by overgrazing.

One thing at least has been conclusively proved in this experiment, i. e., that the perennials which once flourished here and which have been decidedly injured by stock will again regain their ascendency over the weedy annuals when given a measure of protection. The *Bouteloua rothrockii* and *Bouteloua bromoides* areas were not only less productive of these perennial grasses when the inclosure was made but were actually more productive of the annuals *Bouteloua aristidoides* and *Aristida bromoides*. (See Pls. II and III.) The gradual encroachment of the perennials upon the region of annual grasses has been one of the most notable features since the area was inclosed, and is yet in all probability only partially accomplished.

The regaining of ascendency by the perennials is slow here, much slower than in regions favored by a more equitable rainfall. As stated elsewhere, it is only in an occasional season that seed of the perennials appears to find conditions congenial for growth. This, coupled with the fact that the annuals invariably encroach at this altitude whenever the perennials are injured, renders the process of recuperation slow here compared with that in northern regions of more favorable rainfall and a less easily eroded soil.

On the other hand, the increased growth of an even partially protected area is phenomenal. One of the inclosures completed very late in 1907 can be distinguished at the present time for miles by the difference between the character of its vegetation and that of the vegetation outside, and it has been grazed continuously at that, but only moderately.

Last season one of the fields inclosed was as badly grazed as the Macaranthera area already referred to, but grew a fine crop of a yellow annual composite. Although it was in one of the best perennial-grass regions on the west side of these mountains, there was practically no grass there except a poor growth of the six-weeks' varieties. This season there is, of course, after such excessive graz-

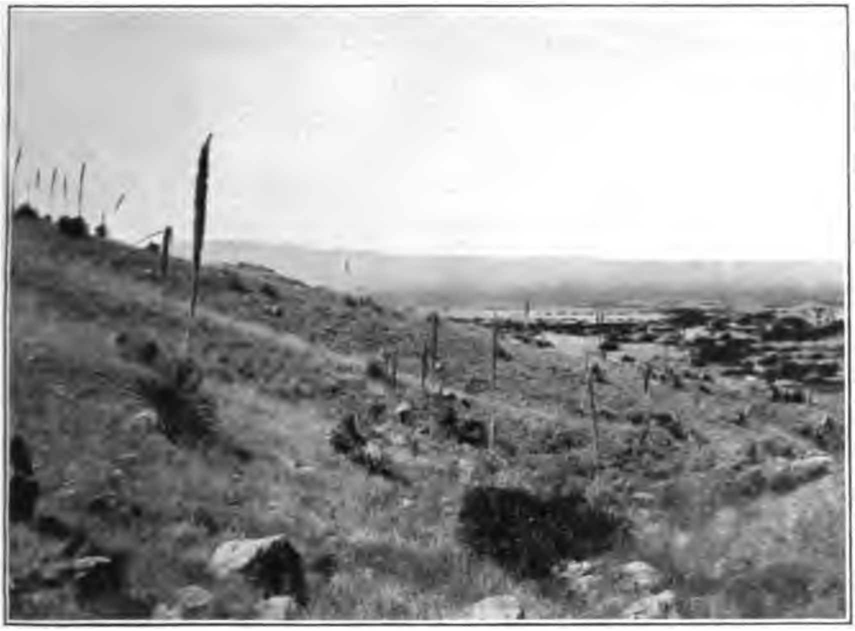

FIG. 1.—A CLOSE VIEW OF THE SOUTHEASTERN PORTION OF THE INCLOSED AREA.

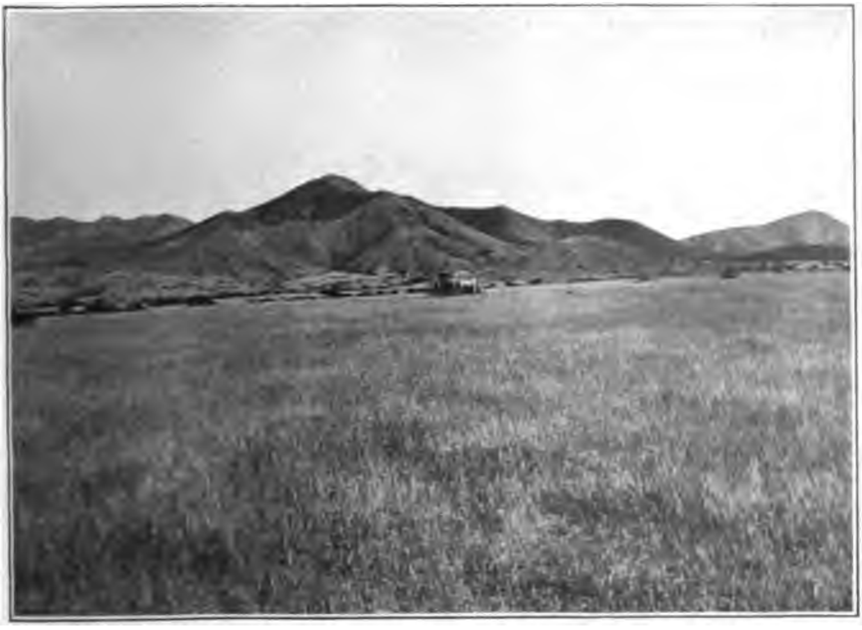

FIG. 2.—GENERAL VIEW OF THE SOUTHEASTERN PORTION OF THE INCLOSED AREA.

VIEWS IN THE INCLOSED AREA.

ing, only a moderate growth of the perennials, but at least tenfold as much as there was last year, and a very heavy growth of the annuals. Judging from what has taken place upon the first large inclosure, the annuals will gradually give way to the perennials during the next four or five years and at the same time withstand a considerable amount of grazing.

Below an altitude of about 3,500 feet we come to the desert proper, where the summer grasses are mainly of the annual type, always have been, and probably always will be. Below this altitude the only perennial grasses are those which are favored by occasional irrigation, in long arroyos and swales, where the drainage from higher levels spreads out over them. There is no hope of establishing perennials upon the lower, unirrigated mesa lands. When rains are favorable the low-lying regions will produce some indifferent feed in the shape of annuals, and that is all that can be hoped for them.

PECULIARITIES OF THE FEED.

The appearance of the feed upon the ground is deceptive in any desert country, but more especially in the area described in this bulletin. The growth is invariably thin, but it may be quite tall, especially in favorable years, making difficult an estimate of the quantity of feed produced. This is true of the growth in general upon a desert region. The most deceptive grass of all is the one locally known as black gama (*Muhlenbergia porteri*). (See Pl. IV, fig. 1.) In early days this grass was exceedingly conspicuous, growing in tangled masses 2 to 3 feet high, both in clumps of shrubbery and in the open. The pioneer stockman calculated the productivity upon what he saw of this species, supposing that he was dealing with a grass of ordinary character. But the pioneer saw three or four years' growth, for the culms of this grass are perennial, only the terminal joints dying back each season. When, therefore, an area is unpastured for a time there is actually an accumulation of feed from year to year of this grass and some others, while the ordinary grasses die and grow up again from the roots each year. The deception is really serious, as is readily seen if one mistakes three or four years' growth for one and stocks the land accordingly. This is precisely what has happened in many cases. It is no wonder that some managers of stock companies insisted that the country could not be overstocked, nor, indeed, would it probably be if the production which the pioneer saw could be repeated with certainty each year.

WEEDS.

There are really but two weeds in the inclosure, but they are both somewhat serious. One is one of the rayless golden-rods (*Isocoma coronopifolia*) (Pl. IV, fig. 1), not distantly related to the sheep weeds and snake weeds of New Mexico, Texas, and northern Arizona. Here this plant has spread upward from the river bottom and now occupies the rocky ridges and mesas between the grassy section and the more level desert lands below. It has thickened and increased perceptibly during the last five years. The rainfall in the region where it is most abundant was very light in 1908, and it consequently made but little growth. No one can tell what the future of this plant may be; it is quite probable that the grasses unmolested would hold their own against its encroachments, but with the grassy vegetation weakened by grazing it may increase to such an extent as to crowd out nearly all of the valuable plants, as is done over thousands of acres in other regions by species of Gutierrezia.

Remedies which are effective and at the same time economically applied in the control of the variety of rayless golden-rod mentioned have not been perfected as yet. Burning in the dry season in summer will kill some species of the group. In other words, if there is sufficient herbage upon the ground to burn during the vegetative condition of these plants they will be killed by burning the land over, but burning during the winter season, when they are dormant, will not kill them.

In the region under consideration the golden-rod referred to has increased mainly below the grassy area, such increase having taken place but partially during the time that the area has been under protection. The encroachment evidently had begun years before. It is not yet thick enough to burn, even during the dormant dry season. Should all the young plants in evidence in 1908 come to maturity, which is rather improbable, it would be thick enough to burn in two or three years. The grasses do not become abundant enough here to allow of burning. The weed is increasing in the lower grassy areas, but principally in that region which now, as probably always, is producing mainly annual grasses. How far it will increase in the perennial-grass areas and how its encroachments within and without the fence will compare can not yet be satisfactorily judged. It must be remembered that it takes very much longer to secure positive results in matters of this kind in this region of scanty rainfall than in more favored localities. There are indications that the plant has about reached the limit of its growth here, as the sheep weeds have elsewhere, and like them has begun to die. In 1909 a large proportion of the plants were dead and none were as vigorous as in previous years, although the season was exceptionally favorable.

The only other real weed is the loco weed (*Lupinus arizonicus*). This is supposed to have done much damage to the horse industry, but does not appear to be as injurious to cattle. So serious is the matter considered that at least one rancher in the vicinity has gone out of the horse business entirely.

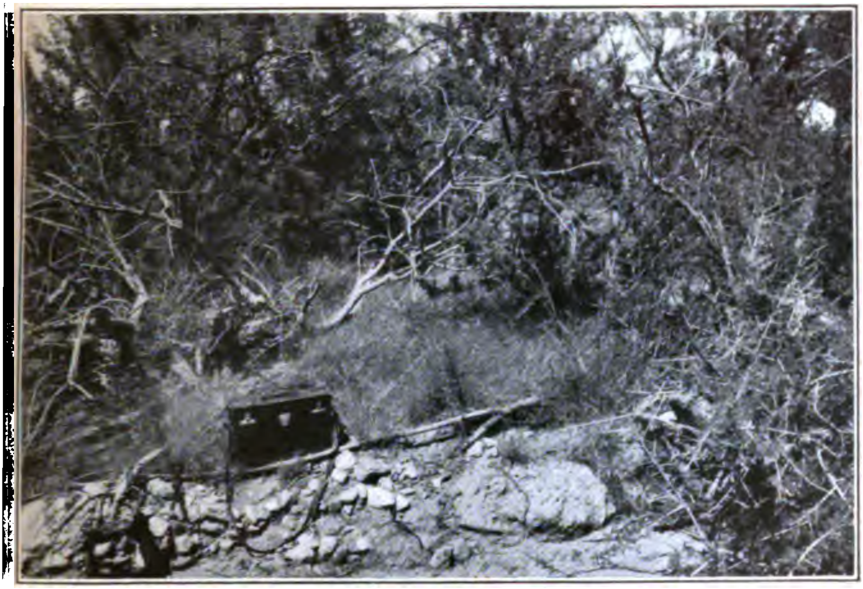

FIG. 1.—MUHLENBERGIA PORTERI GROWING UNDER THE PROTECTION OF A CAT-CLAW.

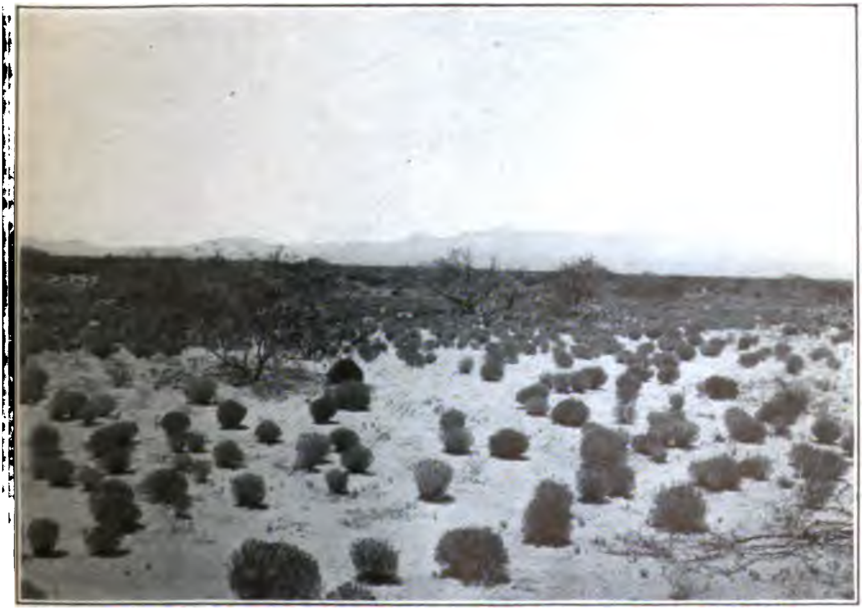

FIG. 2.—ISOCOMA CORONOPIFOLIA GROWING ON RANGE LAND.

TWO GRASSES GROWING IN THE INCLOSED AREA.

This lupine is an annual plant which grows in the winter rainy season. It is conspicuous in the southern portion of the inclosed area in February and March. In favorable seasons it gives its characteristic blue color to the landscape upon hillsides and bluffs along arroyos. Even this plant is closely grazed by cattle, with, as already stated, apparently no injury. Upon the outside of the area it is grazed as closely as any other forage plant and seems to be as readily destroyed by such grazing as any of the valuable feeds. In the spring of 1908 it was difficult to find any of this plant outside of the fence in localities where it has been very abundant. The rayless golden-rod is the only conspicuous weed not touched by stock.

YIELD OF VEGETATION.

During the time that the area has been under fence an effort has been made to get a quantitative estimate of the amount of herbage produced from year to year. The estimate is based upon measurements of definite plats scattered over the entire field in such a way as judgment dictated would give an average yield. Only the briefest outline of the data secured is given here. The method of measurement is given in Bulletin 67 of this series and need not be repeated here in detail. In general it may be said that the vegetation of plats containing 21 square feet was measured, these plats, eighteen to twenty in number, being scattered over the entire field, as indicated in Bulletin 67. In that publication a more or less detailed discussion is given of methods employed in making these computations, which need not be repeated here. Inasmuch as these are more or less estimates anyway, it is not important that in this paper a slightly different method of computation is used from that in Bulletin 67. The comparisons are not altered.

The results of these measurements are given in the following table:

TABLE I.—*Average yield of forage on plats of 21 square feet each in the fenced area on the Coronado National Forest.*

Year.	Season.	Rainfall.	Seasonal yield.	Annual yield.
		Inches.	*Pounds.*	*Pounds.*
1903	Spring	3.29	520.55	791.02
	Summer	7.48	270.47	
1904	Spring	2.64	14.13	412.45
	Summer	8.24	398.32	
1905	Spring	20.70	799.00	1,174.94
	Summer	6.14	375.94	
1906	Spring	9.88	(a)	(a)
	Summer	3.27		
1907	Spring	7.98	435.88	1,151.76
	Summer	12.03	715.88	
1908	Spring	9.36	300.88	1,225.55
	Summer	10.67	924.67	

[a] No measurements.

In the production of the two crops of feed which we have in region of the Coronado National Forest two seasons of rainfall tribute. The season which produces the spring crop is much indefinite than the one producing the summer crop and the themselves are very different. The spring feed consists of annuals, and the summer feed of grasses, both annual and peren

The winter rainy season, as it is usually called, may begin as as October and may last through April, or it may be foreshor at either end and even almost disappear at times. The rainy season, on the other hand, is short, commonly better dist and occurs in July, August, and September. In the col Table I showing rainfall, that recorded under the spring sea between October and April, and that under the summer se July to September. The rainfall of May and June is negligi seldom has any influence on feed production.

The rainfall record is taken in the 204-acre pasture shown map (fig. 1).

In a general way Table I shows that the yield is dep upon the quantity of rainfall. Quantity, however, is not the factor, as will be readily seen. Its distribution is of extra importance. This feature is not shown in the table. It can shown only by a detailed account of the precipitation, which it not considered necessary to publish at this time. The most im portant point of all brought out by the table is the comparati uniformity of production during the last years and the increase ov earlier years. Both of these facts tend to show that the producti of the field has been decidedly on the increase and that it may no be at its maximum, which was reached in about three years after i inclosure. Whether the production from now on will be depende upon rainfall alone remains to be seen, but so far as these records that is to be expected. It is also to be expected that from now o there will be little, if any, increase in production due entirely t protection. On the other hand, yield alone is only one phase of the improvement which may take place. As pointed out elsewhere, this improvement may be as much a matter of the supplanting of annuals by perennials of greater value as it is of actual number of pounds of feed produced. This improvement, it is believed by the writer, will take place to some extent under future protection, but it is believed that the maximum tonnage has been reached and that future fluctuations will be due in largest measure to variation in rainfall.

The general correlation between the rainfall and the yield of forage is of course very striking, as rainfall is always the most important factor of production here. But the production of 520 pounds of forage on 3.29 inches of rainfall in the spring of 1903 is out of all

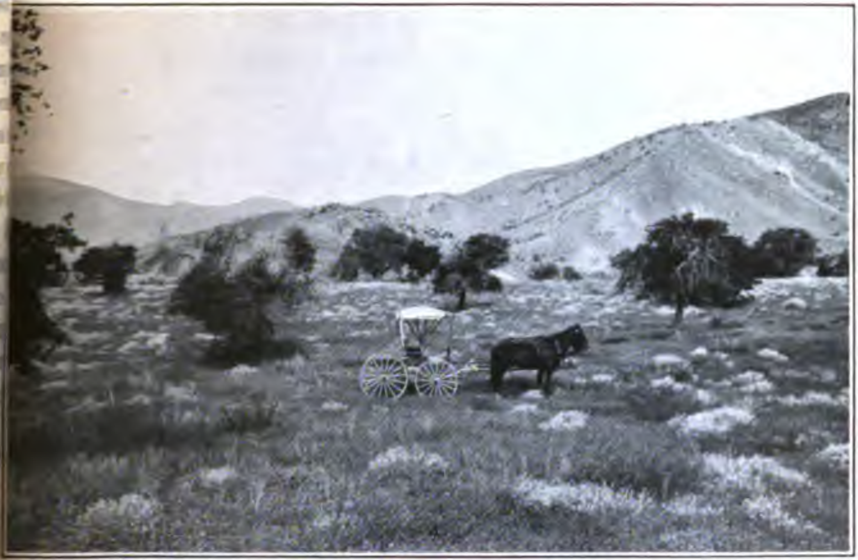

FIG. 1.—A BADLY OVERGRAZED AREA IN THE "MACB." PASTURE.

The greater part of the vegetation consists of worthless composites and eriogonums. The latter are fairly good feed. Photographed in September.

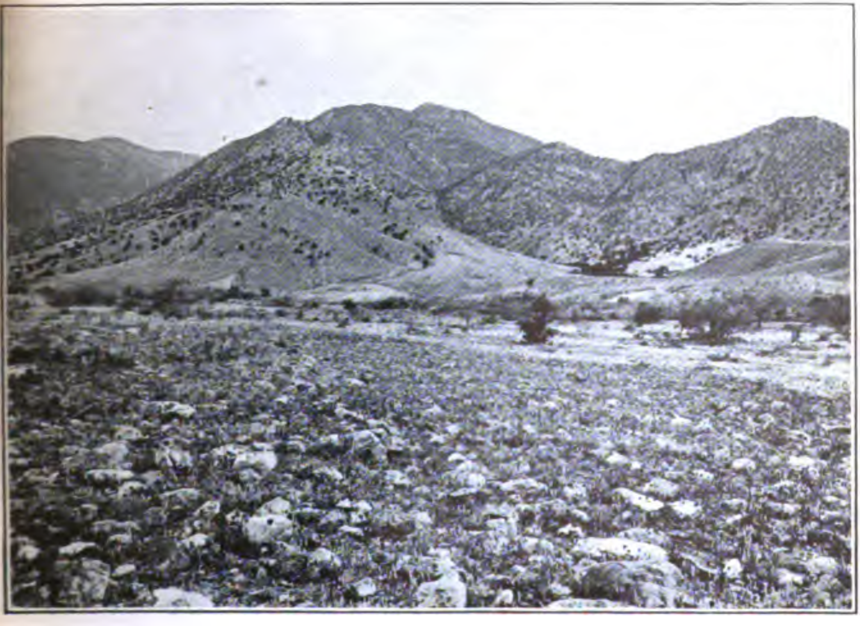

FIG. 2.—UPPER PORTION OF THE 590-ACRE PASTURE, SHOWING SPRING VEGETATION UNDER HEAVY GRAZING.

HEAVILY GRAZED PASTURES IN THE SMALLER INCLOSURE.

proportion to the production of only 14 pounds on 2.64 inches in 1904. As a matter of fact nearly 2 inches of the rainfall which produced the spring crop of 1904 fell in the months of October to December. This served to germinate the seed very well, but there was not moisture enough in the spring to make any considerable growth. This is a good illustration of the influence of proper distribution of moisture as well as proper quantity.

CARRYING CAPACITY.

As stated elsewhere, the large field has not yet been pastured, the object thus far being to study recuperation under absolute protection. The only data secured on carrying capacity are from the pastures under private cooperative control contiguous to the upper side of this field. The most satisfactory record, all things considered, is from the "MacB." pasture. (See Pl. V, fig. 1.) The record is short, but even the first year after being inclosed the land improved very perceptibly and still maintained stock at the rate of one head to 20 acres. It should be stated that this pasture is about one-fourth in the oak belt and the remainder in the open grass land immediately below. It is probably the best pasture land in this region. The 204-acre pasture is smaller and less productive by far, mainly on account of thick brush. A long record, reaching over five years, is available for this pasture. Four burros and three horses run short of feed in this pasture occasionally. Of course, the brush interferes with the growth of grass somewhat. On the other hand, the mesquite (*Prosopis velutina*) furnishes some beans, which are a valuable forage. Pasture experiments in the large inclosure were begun in the summer of 1909, and the results will be reported later.

INCREASE OF SHRUBS.

Much has been written about the rapid spread of the mesquite (*Prosopis glandulosa*) and other shrubby vegetation in Texas since the advent of flocks and herds, but the development of this class of plants is so much slower on the inclosed area referred to in this paper that it appears to have been in a large measure overlooked. It is, however, taking place just as surely as in Texas; the only difference is that the growth is much less than half as rapid.

The year previous to the inclosure of the large field a small crop of hay was cut over the best portion of its present area. This, however, was far from any water. Acres were harvested where there was no impediment to the mower. At the present time, six years later, there is not an acre in the whole field where there are no shrubs to interfere with the machine. They are still small, half an inch to an inch in diameter at the base, but large enough to stop a mower.

They have made a very perceptible increase within the writer's acquaintance with the area. The prediction is ventured that the time is coming when these foothill grassy areas, which now have only an occasional small shrub, will be as shrubby as the deserts and lower foothills below them, if not more so.

Some of these shrubs do, of course, furnish some feed, but here, as elsewhere, their growth will be largely at the expense of grasses. For a long time the lower foothills, arroyos, and general desert mesas have been shrubby, and the gently sloping tables between the arroyos and the upper foothills are slowly becoming so.

It will doubtless be impossible to depict all the agencies that are bringing about these changes. It is quite certain that the operations here of the Bureau of Plant Industry have had no influence, for the shrubbery has thickened up on the outside of the inclosure, where the grazing has been very heavy, apparently as much as on the inside. The probability is that neither protection nor heavy grazing has much to do with the increase of shrubs here, but that it is primarily the direct result of the prevention of fires. There never was a time when the shrubby lower foothills and desert mesas produced vegetation enough, except in limited localities, to allow fires to spread, but the grassy foothills, which constitute the upper half of our inclosure, produce sufficient vegetation to burn readily, at least every other year, at the present time. Previously, before the country was stocked, it probably produced more grass than it does now, and was frequently burned over, the fire extending as far down as vegetation would permit. Such burning did comparatively little injury to the grasses but was very destructive to all small shrubs; consequently, these were able to exist only along the sandy washes, where the grasses were least productive, and upon the lower areas, where fires did not molest them.

Upon the brushy deserts below, the rainfall is so scanty that the grass produced is not sufficient to allow fires to spread. Upon the mountains above, the moist season is more prolonged, the grass remains green longer, and the surface is more broken, often with sheer declivities, which are bare of vegetation, all of which render burning less probable. It must be remembered that frequent burnings are not necessary here to keep down brush. Possibly with comparative freedom from grazing a fire once in ten years would suffice in such an area, because growth is very slow.

The memory of early stockmen is not sufficiently retentive to give us much reliable information regarding the location and density of brush upon these areas when their operations began, so it is necessary to make inferences from changes which are occurring now under the changed conditions. Trained observers have not been sufficiently

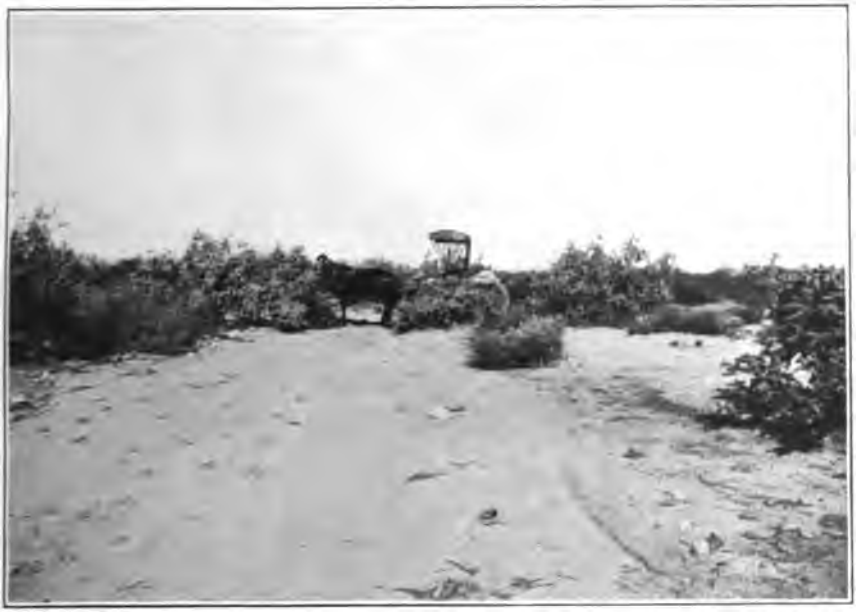

FIG. 1.—AN ARROYO PRODUCING BRUSH AND CACTI BUT VERY LITTLE GRASS.

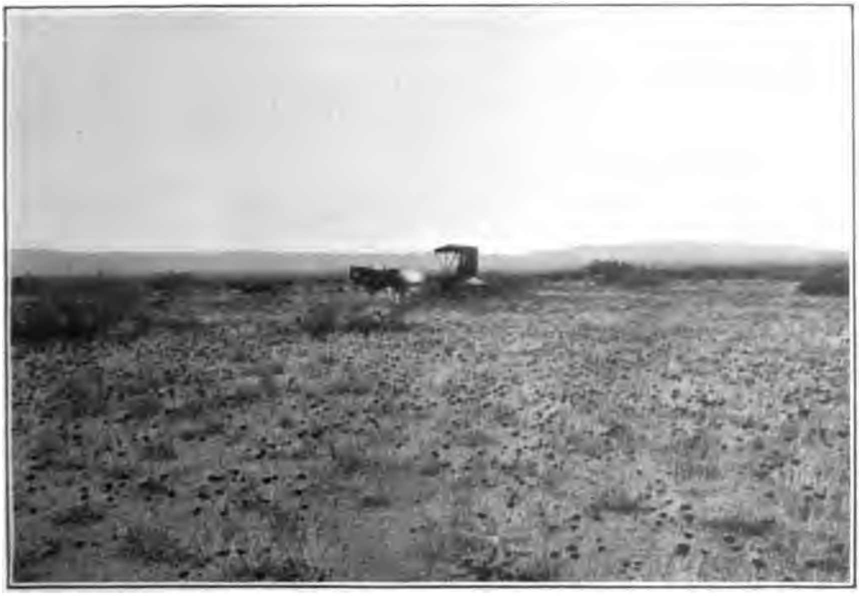

FIG. 2.—FIELD CONTAINING BAILEYA MULTIRADIATA, A CONSPICUOUS PLANT ABOUT THE LOWER BORDER OF THE PERENNIAL-GRASS REGION.

AN ARROYO AND A PERENNIAL-GRASS FIELD IN THE INCLOSED AREA.

long associated with the conditions or interested in this phase of desert vegetation to form from memory accurate judgments.

It is true that the grassy belt is noticeably not continuous in these mountains or elsewhere, but on the other hand, the desert mesquite forest often extends quite to the beginning of the real mountain forest. Such a condition is easily accounted for by local influences. In the canyons the growth of timber is continuous from the mountains to the desert, and in places on the ridges and gently sloping mesas as well (Pl. VI, fig. 1). In both cases the writer believes this condition to be due mainly to the comparatively low fertility of the soil in these situations, assisted in the canyons by the excess of water. The bottoms of the canyons are less productive of grass here to-day than the mesas between, owing to the constant shifting of the sands and the washing off of the finer particles of soil by the frequently changing courses of the flood waters. Action of fires was therefore less pronounced in the canyons, allowing trees and shrubbery to get started, as well as when they did get started, furnishing greater moisture in the subsoil.

The main factor, though, in the opinion of the writer, has been that of fire. It is firmly believed that were it not for the influence of this factor the grassy mesas would to-day be covered with brush and trees, the same as the canyons, except that the growth would be smaller, owing to a more limited supply of moisture. In short, the same laws apply here that govern in our great prairie States (see Pl. VI, fig. 2), where the treeless plains were kept so by frequent fires. It is a very conspicuous fact that the continuance of the desert forest, up to the mountains upon the mesas, occurs where the soil is poorest; in other words, upon the lands which produced least grass, and, consequently, the smallest amount of food for fires. This fact is illustrated in one of the pastures, where there is an area of mesquite upon the gently sloping mesa. But this area is naturally poor soil, and its poverty, on account of location close to the terminus of a temporary stream, has been aggregated for many years by excessive grazing. The same remarks apply to the region just north of Helvetia.

The spread of the seed of the mesquite by cattle and horses eating the beans, thus furnishing a good culture for their development, may have some influence, but it is so seldom that seedlings are met with that it is questionable whether cattle or horses have as much influence as has been suggested. They probably do cause a more thorough and widespread distribution, but probably assist the spread of shrubbery more by eating off the grass, so that there is nothing to burn, than they do by distributing the seeds.

SUMMARY.

The lands under consideration in this paper appear to regain their original productivity in approximately three years of complete protection.

Evidence thus far secured seems to indicate that the best lands in the vicinity will improve under stocking at the rate of one bovine animal to 20 acres. The poorer lands take a correspondingly larger acreage for each animal. The areas that will carry now one head to 20 acres are very limited.

Brush and timber are encroaching upon the grass lands, due, it is believed, to protection from fires.

A ground cover is not a factor below an altitude of about 3,500 feet.

Although the maximum yield of forage may be reached in about three years of protection, improvements in quality of forage will probably go on longer through the continued supplanting of annual plants by perennials of greater value.

Thus far alfilerilla is the only introduced plant which has succeeded, and this only in the most favored situations. It does not appear to thrive in competition with the native perennial grasses at these altitudes when the latter are not grazed.

None of the other two hundred lots of seed sown have given any promise of success except those of three or four native species. These give beneficial results, but the cost is high.

Results seem to be secured much more rapidly by proper protection from overgrazing than by any other method.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 178.
B. T. GALLOWAY, *Chief of Bureau.*

IMPROVEMENT OF THE WHEAT CROP IN CALIFORNIA.

BY

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ASSISTANT AGRONOMIST, OFFICE OF GRAIN INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 28, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Improvement of the Wheat Crop in California," by Mr. Henry F. Blanchard, Assistant Agronomist in the Office of Grain Investigations, and recommend its publication as Bulletin No. 178 of the series of this Bureau.

For many years there has been a steady deterioration in the wheat crop of California, due to two general causes, (1) bad methods in farm practice and (2) a lack of varieties adapted to that region. The Office of Grain Investigations, of this Bureau, has investigated these conditions for about five years, during a part of which time the work has been in cooperation with the state experiment station at Berkeley, Cal. Besides observations on many farms and other investigations, experiments in methods of cultivation and adaptation of varieties have been conducted in detail at two points, Davis and Modesto. The accompanying paper gives briefly some of the results of investigations, to date, along these lines.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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IMPROVEMENT OF THE WHEAT CROP IN CALIFORNIA.

INTRODUCTION.

An impression exists among many California farmers that the soil will no longer produce profitable yields of good milling wheats. This impression is strengthened by two well-recognized facts: (1) That under past and present methods of wheat culture the soil is failing in many localities to produce as large crops as heretofore, and (2) that the Australian and Club varieties, the most widely grown California wheats, are extremely starchy. As only these very starchy varieties have been extensively grown, it has become necessary for the millers to import large quantities of Turkey wheat from the Middle West to blend with the California wheats.

In order to discover varieties better adapted to California needs than those commonly grown, the Office of Grain Investigations of the Bureau of Plant Industry has for a number of years conducted extensive tests of wheat varieties, including many of foreign origin. In this way it was hoped to improve the California wheat crop in both yield and milling quality. As improved methods of cultivation are necessary also to obtain profitable yields of nitrogenous wheats, an effort has been made to determine the effect of deep plowing and the addition of humus to the soil in the form of winter green-manure crops. The time of plowing, the conservation of moisture, and the eradication of weeds have also been considered. If the State is to continue the profitable use of its grain lands and derive from them the largest possible return, it is quite necessary that there be an improvement in the general practices of cultivation and in the varieties grown.

The investigations covered by this report are in general based upon results obtained and observations made during a number of years, a part of the time in cooperation with the California Agricultural Experiment Station. An effort has been made to so correlate the results and observations that they will be of benefit to the California grain grower in effecting improvement in soil fertility, in the yield of wheat to the acre, and in the milling quality of the grain produced.

The investigations carried on thus far are simply the foundation for a more extensive work in the future. It is necessary in order to find a few desirable varieties that a large number be first grown in small areas and compared with the commonly grown varieties. The results obtained in this way indicate which varieties may be submitted to practical tests directly with the farmers.

COMMON METHODS OF CULTIVATION UNSATISFACTORY.

The cultivation methods still commonly practiced by many of the farmers of California have been brought about by the conditions existing about 1860, when it was first discovered that wheat could be grown as a profitable crop. These conditions were as follows: Fertile virgin soil, large level valleys facilitating extensive cultivation, a growing season extending from November to June, and a period of rainfall extending over the growing season, with comparatively high temperatures during the winter months and low temperatures during the spring months. The methods are generally very simple and very crude. They consist in the continuous cropping of wheat and barley upon soil which receives only a very shallow cultivation. The farmer is removing the plant food from the soil without the addition of anything to take its place. This is resulting in many localities in a depleted condition of the soil, and profitable crops of wheat are no longer grown.

ORIGINAL METHODS OF CULTIVATION.

The first grain producers of California attempted to crop as large an acreage as possible at a minimum cost. In order to do this, at that time all that was necessary was very shallow plowing (3 or 4 inches in depth), broadcasting the seed, and harrowing it into the soil. This was continued from year to year and fairly good crops were produced for a while. The header and stationary thrasher were used in harvesting the grain. Very little attempt was made on the part of the producer to secure pure seed of the varieties grown or to practice the careful grading of wheat, using only the largest and best kernels for seed. In fact, very little attention was given to the seed used. In many instances the farmer used the poorest grade of grain that he had grown the previous year.

CHANGES FROM ORIGINAL METHODS.

Since the earlier period of wheat production in California some changes have taken place or are now in progress. The most important of these are the replacing of the header and stationary thrasher by the combined harvester and the beginning of the practice of summer-fallowing the land.

The change to the combined harvester, about 1880, was due largely to labor conditions existing at that time. It was difficult to secure enough men to properly handle the grain, and the methods of harvesting were unsatisfactory. The climatic conditions, as well as the general contour of the land, were found to be favorable to the use of the combined harvester. This machine reduces to the minimum the number of men employed and at the same time utilizes the power of mules and traction engines.

Proper methods of summer-fallowing the land are not yet generally practiced. Summer-fallowing became necessary on account of the foul condition of the soil which had been produced by continuous cropping to wheat. The use of the combined harvester, however, has partly offset the cleaning effect of the fallow. This method of tillage is beneficial, especially when it precedes a particularly dry season, as in this way a large amount of the rainfall for two years is retained in the soil. At first it was found necessary to summer-fallow the land every third year only, but later, every second year.

Other changes which have been taking place during recent years are the reduction in size of a few grain farms and an increase in the depth of plowing on the part of some farmers. These changes, however, occur in individual instances only and are not general in their nature.

BAD RESULTS OF PAST AND PRESENT METHODS.

We now have in many sections of California, as a result of the common methods of wheat culture, a soil which refuses to produce profitable crops of the commonly grown varieties of wheat. The general practice of single cropping has depleted the soil in humus and nitrates and made it very foul with weeds.

Soil Low in Humus and Nitrates.

There are large sections of California which have been sown in wheat and barley under the commonly practiced methods for the past thirty or forty years. These crops rapidly deplete the soil in humus and nitrates. Humus is the decaying organic material which gives body to the soil and is essential in retaining the soil moisture. It also affects the temperature of the soil, producing somewhat higher temperatures in winter and lower temperatures in summer, according to Wollny, as cited by Hilgard.[a] The nitrates of the soil are very essential in the production of wheat, as they form an important part of the necessary plant food. A soil low in nitrates usually tends to decrease the nitrogen content of wheat grown upon it. On soils low in humus and nitrates there is also a correspondingly low yield of wheat.

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[a] Hilgard, E. W. Soils, 1906, p. 306.

SOIL FOUL WITH WEEDS.

The weed problem is not of minor importance. In fact, when passing through California grain fields and finding that large areas are badly infested with weeds one is impressed with the effect that they must have upon the yields of wheat. This weedy condition is due largely to the common methods of harvesting and cultivating. In many localities the soil has become so weedy that even with the best methods of summer fallowing commonly practiced by the farmer it is impossible to prevent large damage to the crops. The weeds in many instances crowd out the wheat plants by outgrowing them during the winter months.

REQUIREMENTS FOR THE PRODUCTION OF PROFITABLE CROPS.

In order to produce profitable crops of wheat on the worn-out grain lands of California the past and even the present methods of production must in a large measure give way to methods which will produce better results in the future. This to a small degree has already taken place in some sections. There are also large areas of the State upon which wheat has not been grown for as long a period of time as on those sections first farmed. However, these are being rapidly reduced to the same depleted condition on account of the unscientific practices in use.

In some localities where the soil now fails to produce profitable grain crops it has been possible to grow other crops on the same land. In general, such instances are confined to the areas upon which water can be applied. Alfalfa and fruit usually do well in such sections. There are, however, large areas to which water can not be readily applied, and these will no doubt be used for the production of grain for many years to come.

In order to produce crops of grain on such lands it not only becomes necessary to introduce new varieties or improved forms of those now grown, but a change in the actual farming methods for grain as they now exist is absolutely essential. The present methods sufficed for a time, and temporary profits from the soil resulted. It has been comparatively easy to produce crops from a fertile soil without taking into account the effect of such methods upon the soil. It will require much more skill and effort to return the soil to a condition in which good crops of wheat may again be produced.

SMALLER FARMS AND PERSONAL SUPERVISION BY OWNERS.

In the pioneer days of California the interior valleys were not considered of much value for the production of crops on account of the small amount of rainfall. At that time certain companies were enabled to secure large tracts of this land at a nominal price. These companies discovered that this land would produce good yields of grain and it was cropped on a very large scale. Since that time there has been a gradual breaking up of these large farms into smaller ones. However, there are still too many large ones to make probable the general use of improved methods of grain production. Until the farms are so reduced in size that they may be properly handled we may look for continued low production and further depletion in the soil fertility of the wheat lands.

Another feature of much of the grain production in California is the practice of renting the lands from year to year to men who are not interested in the building up of the soil. The desire of the tenant is to get all that is possible out of the land at the least expense to himself during the time which he holds it. As long as this condition exists there will be a continued decrease in the value of the wheat lands. The remedy for this is the direct supervision by the owner of the methods of cultivation and cropping. He has a real interest in the future condition of his soil and will undoubtedly give it better attention than the tenant who is interested only in the crop he produces each year.

IMPROVED METHODS.

Improvement in the methods of wheat culture is essential to the production of more profitable crops. These improvements include the practice of deeper plowing, the increase of soil humus and nitrates by turning under green-manure crops, and the cleaning of the land of weeds by better methods of cultivation.

Deep Plowing.

At the present time we can not place too much stress upon the importance of deep plowing. The few inches of soil at the surface have been skimmed for so long that they are practically devoid of plant food in available form. For this reason alone it becomes necessary to turn up fresh soil. This will necessitate cutting below that stratum of soil commonly known as the "plow pan," which has been formed by the practice of plowing year after year at the same depth. In many localities plowing at a depth of from 8 to 12 inches is advisable. Unless green-manure crops are to be turned under, this depth should be reached by a gradual increase in depth for two or three years. By this gradual increase in depth the subsoil will become properly mixed with the surface soil.

Deep plowing requires more power than is needed for the ordinary method, and the first deep plowing is more difficult than subsequent plowings. This is due largely to a more or less packed condition of the subsoil. Deep plowing should be done in the early spring while there is still sufficient moisture in the soil. It should not be done while the soil is either too wet or too dry. While the benefits derived from deep plowing may not be so evident the first season, the results obtained are of permanent character. The subsoil is benefited by direct contact with the air and other climatic influences, and the effects of deep plowing will be more noticeable the second and succeeding years.

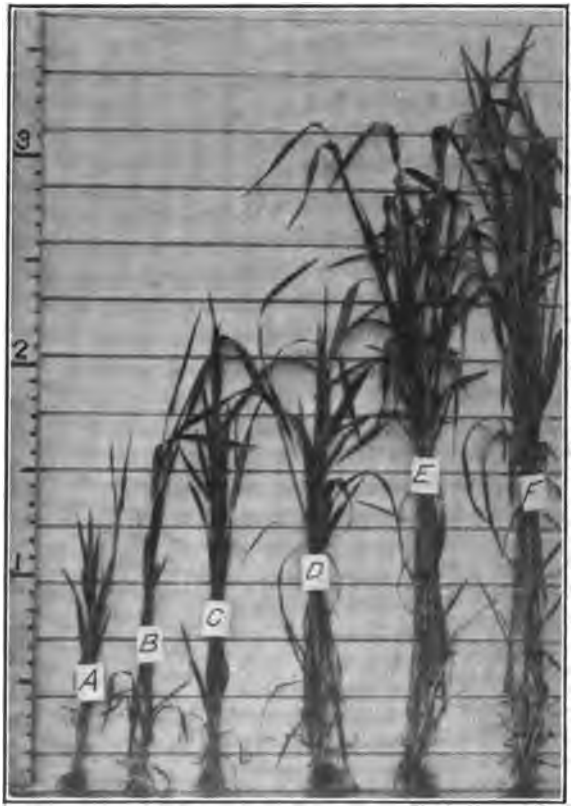

FIG. 1.—Wheat plants from six plats treated differently, showing comparative development: *A*, From plat continuously seeded to wheat; *B*, from plat barefallowed in 1908; *C*, from plat upon which horse beans were grown and plowed under in 1908; *D*, from plat upon which Canadian field peas were grown and plowed under in 1908; *E*, from plat upon which rye and vetch were grown and plowed under in 1908; *F*, from plat upon which rye was grown and plowed under in 1908.

ADDITION OF HUMUS AND NITROGEN TO THE SOIL.

As already stated the soil of California grain lands is low in humus. In order to add humus to the soil green-manure crops must be grown and plowed under. This is necessary not only in order that land very low in humus be again placed in good condition, but also that lands in which humus is now fairly plentiful be retained in good shape (fig. 1). Owing to a tendency of very light sandy soil to shift during heavy winds, deep plowing may be detrimental at first on such soils. This soil shifting may, however, be reduced to a minimum by the addition of humus, which will give it body and make possible the practice of deep plowing without injury.

CROPS TO BE USED AS GREEN MANURE.

Canadian field peas and Abruzzes rye do very well as green-manure crops in the valley sections of the State. Under favorable conditions in the Sacramento Valley peas alone have given very good results when seeded at the rate of 80 pounds to the acre. On the lighter soils of the San Joaquin Valley peas do not make as rank a growth as in the Sacramento Valley. For this reason it is suggested that peas and rye be grown together, the rye to be sown at the rate of 40 pounds and the peas 50 pounds to the acre. The rye and pea vines will add humus to the soil, while the nodules on the roots of the pea vines will transfer the nitrogen of the air to the soil in the form of nitrates. If rye and peas are to be grown separately, the rye should be sown at the rate of 70 pounds and the peas at the rate of 80 pounds to the acre.

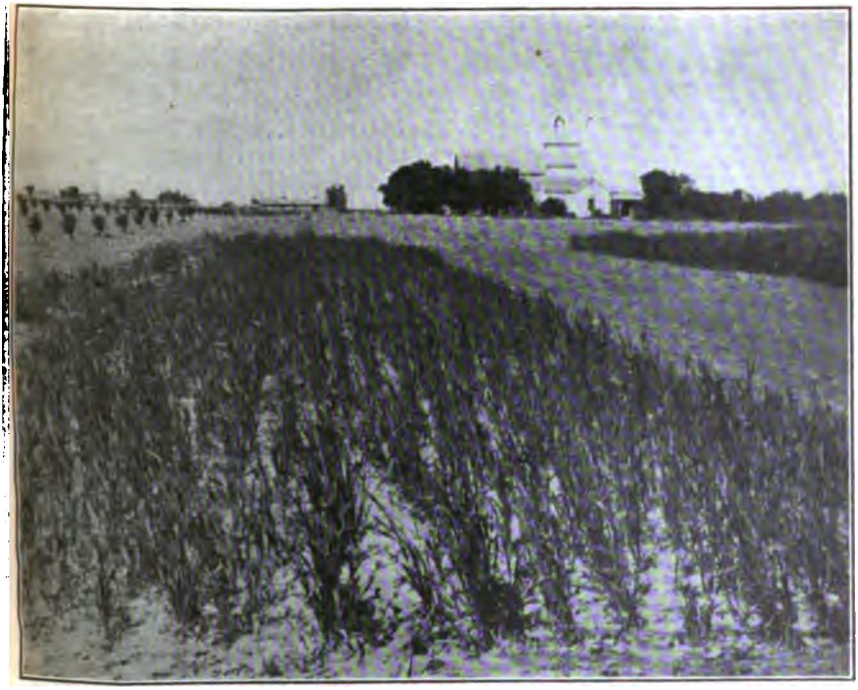

FIG. 2.—Wheat growing on plat which has been continuously seeded to the same crop. (See figure 1, *A*.)

TIME AND METHOD OF HANDLING.

Rye and peas for green manure must be grown as a winter crop. They should be planted as soon as it is possible to plow the land in the fall and should be turned under before the land is too dry for plowing in the spring. Usually there is sufficient moisture in the soil to allow the planting of green-manure crops by December 1, though in some sections and in exceptional seasons the planting may be necessarily later. It is not advisable, however, to sow later than December 15, for unless the early spring rains are so delayed as to facilitate late plowing the green-manure crop will not be of much value. This crop should be turned under during early March before the soil is too dry for deep plowing. In other words, in order to give green-manure crops the maximum period of growth it is necessary to sow as early as the ground can be worked in the fall and to turn under as late as possible in the spring.

The length of the growing period is regulated very largely by the length of the rainy season. The dry condition of the wheat fields in the fall permits a plowing of only 4 to 5 inches in depth when getting the stubble land in shape for the early planting of green-manure crops. The stubble should be double-disked, where possible, immediately after the wheat crop is harvested. The disking prepares the land to retain the moisture already present and to receive the light precipitation coming during the fall months, thus putting it in shape for an early shallow plowing and a good seed bed. In the spring the land should be plowed deep in order to get

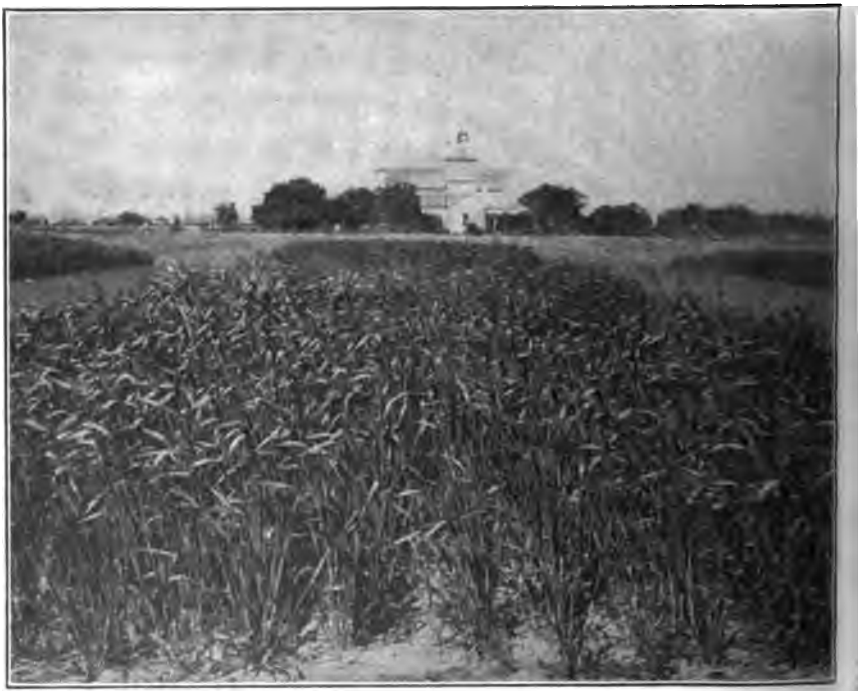
FIG. 3.—Wheat growing on plat on which Canadian field peas were grown and plowed under in 1908. (See figure 1, *D*.)

the growing peas or rye well under, where they will readily decay, after which the soil should be well harrowed immediately.

EFFECT OF DEEP PLOWING AND GREEN MANURING.

The effect of deep plowing and green-manure crops upon the yield of wheat, as determined by observation and actual experiment (see figs. 2, 3, 4, and 5), is shown in Table I, these yields being obtained at Modesto, Cal., in 1909.

INCREASED YIELDS.

While the results indicated are not entirely conclusive, for the reason that they are not based upon trials extending over a long series of years, they give an idea of what may be accomplished by the deep plowing under of green-manure crops. As indicated, horse beans used as green manure appear to give better results than peas. However, they have a very thick and heavy stalk, and an enormous quantity of seed is required on account of their habit of growing a single stalk from each seed. They are not recommended in the place of peas, which will give better results in combination with rye as a green-manure crop.

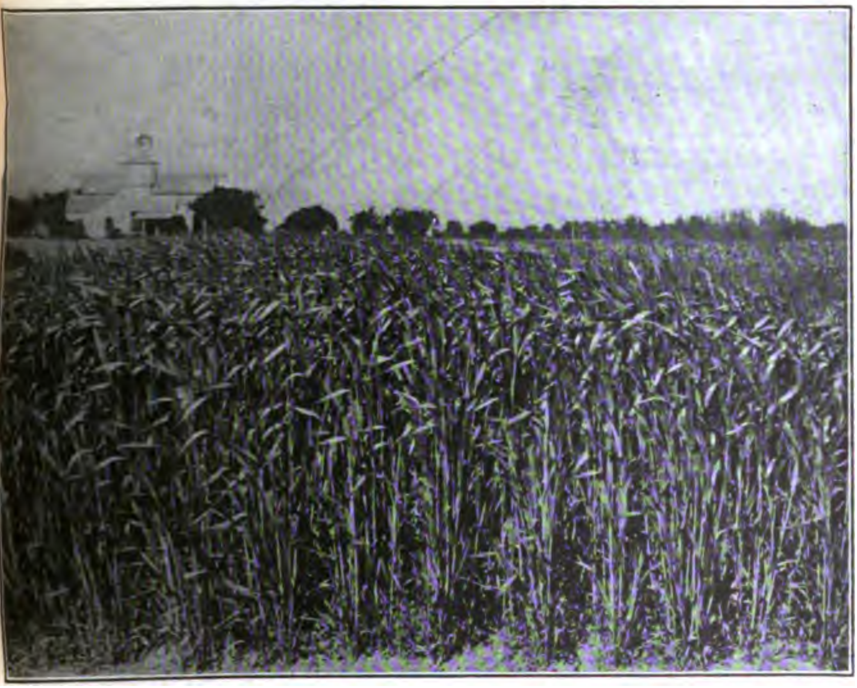

FIG. 4.—Wheat growing on plat on which rye and vetch were grown and plowed under in 1908. (See figure 1, *E*.)

TABLE I.—*Effect of deep plowing and green-manure crops on the yield of wheat at Modesto, Cal., 1909.*

No. of plat.	Preceding treatment or crop.	Yield per acre.	Weight per bushel.
		Bushels.	*Pounds*
1	Fallow	28.00	
2	Horse beans (turned under)	35.33	
3	Canadian field peas (turned under)	33.66	
4	Wheat (26 bushels)	15.66	
5	Rye and vetch (turned under)	50.66	
6	Rye (turned under)	51.33	

The cultivation of the plats indicated in the table was as follow In the fall of 1907 all of the plats were laid out on summer-fallo land and all were plowed to a depth of 6 inches and harrowed. Pl 1 was allowed to remain fallow. Plat 4 was sown to wheat. Pl 2, 3, 5, and 6 were sown, as indicated, to horse beans, Canadi field peas, rye and vetch, and rye alone. The vetch in plat 5 ma a very poor stand, while the horse beans and peas made a fairly go stand. The stand of rye was excellent.

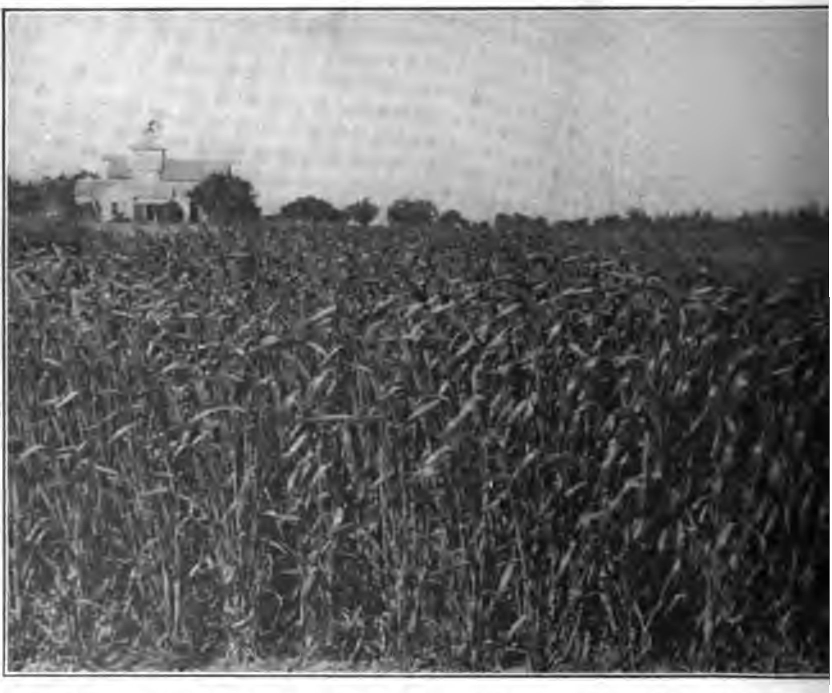

FIG. 5.—Wheat growing on plat on which rye was grown and plowed under in 1908. (See figure 1,

In March, 1908, plats 1, 2, 3, 5, and 6 were plowed 8 inches de harrowed, and kept clean throughout the summer and fall. Plat which yielded at the rate of 26 bushels of wheat to the acre, was double-disked immediately after the wheat was taken off.

The first of December, 1908, all plats were plowed to a depth of 5 inches and sown to wheat. The resulting yields are given in Table I. In two years' time the plat continuously seeded to wheat has produced 41 bushels of wheat. However, the first year's yield, 26 bushels, was produced after summer fallow and the second year's yield, 15.66 bushels, shows a decrease of nearly half. It is quite probable that the third year will give a very low yield and that in a series of five years the quantity of wheat produced from continuously seeded plats would be much smaller than from the other methods of cultivation.

It follows, then, from this experiment, that deeply plowed summer fallow will give much better yields than shallow-plowed, continuously cropped land. Plats 1, 2, 3, 5, and 6 were all plowed at the same depth, and the last four were fallowed also after turning under the green crops. The yields indicate that the addition of organic matter (humus) to the soil is beneficial in increasing the production of crops and that this increase is proportional to the quantity rather than the quality or kind of organic matter added.

INCREASED PROFITS.

The yields shown in Table I were obtained in plat work, where the varieties received the best possible attention, thus giving higher yields than would have been probable under field practice. In our estimate of the increase in profits brought about by thorough methods of cultivation, the yields are estimated at two-thirds the value given in the table.

The estimate made of increase in net profits is based largely upon observation of the general cost of farm work in the State. It may not be absolutely accurate in every particular, but it serves well in bringing out a comparison of the common methods of cultivation employed with the more intensive methods suggested in this paper.

Approximate cost of cultivation per acre by the common method.

First plowing (5 inches deep)	$1.25
Second plowing (5 inches deep)	1.25
Two harrowings	.20
	2.70

Approximate cost of cultivation per acre by the improved method.

Double-disking stubble	$0.50
First plowing (5 inches deep)	1.25
Second plowing (8 inches deep)	2.00
Third plowing (4 inches deep)	1.25
Three harrowings	.30
Rye seed for green manure	2.00
	7.30

The approximate cost of cultivation by the common method is \$2.70 per acre, as compared with \$7.30 per acre by the improved method suggested, which gives an increased cost of \$4.60 per acre for better tillage. As shown in Table I, we have almost doubled the yield per acre by the improved methods. Suppose the yields given in the table were reduced to two-thirds their value, as previously suggested. We still have wheat, following ordinary methods of bare fallow, yielding at the rate of 19 bushels per acre, while wheat following deep plowing and rye as a green-manure crop yields at the rate of 34 bushels per acre. With wheat at \$1 a bushel we have at a cost of \$2.70 per acre produced \$19 (not deducting cost of harvest, etc.). By better methods at a cost of \$7.30 per acre we have produced \$34 (not deducting cost of harvest, etc.). This gives an approximate increase of net profit of \$10.40 per acre in favor of the better method of tillage.

Cleaning the Land of Weeds.

The problem of cleaning the land of weeds reduces itself to systematic cultivation and the production of rapidly growing varieties, especially as concerns their early development. Where cultivated crops are grown it is readily understood that the problem of getting rid of weeds is not so difficult as with wheat crops. Results obtained lead us to suggest that the following method of cultivation, if rigidly enforced, will help in a large measure to reduce the weeds in wheat fields:

(1) Thoroughly double-disk the land as soon as possible after harvest, thus stirring the surface, breaking up the stubble, and covering the weed seeds. Then allow the land to stand until the weed seeds at the surface have had a chance to germinate after the first rains.

(2) As soon as the weed seeds are well germinated, plow the land to a depth of 4 or 5 inches and harrow well. This should be done, if possible, not later than December 15.

(3) Between March 1 and 15, plow to a depth of from 8 to 12 inches. This exposes the weed seeds not turned up by the first plowing. Harrow the surface thoroughly immediately after plowing. Whether a summer crop is grown or the land is allowed to lie fallow it should be kept well cultivated and free from weeds.

(4) In November, plow to a depth of from 4 to 5 inches and sow the wheat about 2 inches deep.

(5) Just before the grain appears through the surface the land should be thoroughly double-harrowed in order to kill all weeds which have germinated following the seeding of the wheat.

(6) The variety of wheat grown should make a rapid, erect, early growth in order that it may keep ahead of and choke out all the young weeds which are not killed by the final harrowing. (Our

investigations tend to prove that the flat-growing types of true winter wheat will not succeed in the valley soils of California, especially in their present condition of weediness.)

(7) The young grain should be thoroughly harrowed as soon as the ground is dry enough in the early spring, thus covering all of the young weeds which have started during the rainy season.

DEVELOPMENT OF BETTER VARIETIES OF WHEAT.

The proper cultivation of the soil is essential to the production of good yields of all varieties of wheat. It does not follow, however, that every variety of wheat will give good yields even on fertile soil properly cultivated. This erroneous idea prevails among certain grain growers. The United States Department of Agriculture has tested hundreds of varieties of wheat in different sections of the country and has found that comparatively few of these varieties are adapted to the prevailing climatic and soil conditions of each section. Varieties which produce good yields in one section of the country are found to be absolute failures in other sections.

VARIETY TESTS IN CALIFORNIA.

Although a large number of varieties of wheat have been tested in California by this Department during the past five years, very few of these are adapted to the climatic and soil conditions of this State. California presents such a variety of climates that a type of wheat which may give excellent results in one section of the State does poorly in another. Our investigations thus far are not of long enough duration to enable us to state definitely the variety of wheat best adapted to any particular locality of the State. However, the results indicate that for the localities in which tests have been made we have now varieties which are better adapted to the prevailing conditions than those commonly grown by the farmers. We are able, therefore, with a fair degree of certainty, to recommend varieties for a large portion of the State.

Table II presents a list of some of the varieties of wheat which have been grown in California in connection with the investigations of the Department. The average yields to the acre, the number of days required to reach maturity, and the fruiting period (the number of days between the time of blossoming and the time of ripening) are based upon the plat experiments continued for three years in the San Joaquin Valley. The results obtained from the same varieties when grown in the Sacramento Valley compare very favorably with those indicated in this table. A few of these varieties are proving to be well adapted to both the localities in which they have been grown.

TABLE II.—*Results of variety tests of wheat in the San Joaquin Valley, California.*

Grain Investigations No.	Variety.	Manner of early growth.	Average number of days maturing.	Average number of days in fruiting period.	Quality of grain.	Nonshattering character.	Average rate of yield per acre.	Weight per bushel, 1909.
							Bushels.	*Pounds.*
1698	Allora	Erect	180	45	Starchy	Good	38.08	61
3019	Australian	Semi-erect	194	38	do	Fairly good	35.96	61
2511-2	Blé Noir	do	161	39	Medium starchy.	do	48.11	58
2921	Bolo Blanco	Erect	191	46	Starchy	Good	58.39	62
2986	California Gem	Semi-erect	198	38	do	Fair	29.78	61
2210	Cap Sheaf	Spreading	189	38	do	do	32.49	60
2227	Chul	Erect	187	41	Glutinous, spotted.	Very good	44.56	63
3018	Club	do	165	41	Starchy	Good	13.98	59
1437	Crimean	Spreading	199	35	do	Fairly good	26.55	63
2988	Dietz Amber	do	194	37	do	Fair	25.68	62
1697	Early Baart	Erect	162	38	do	Fairly good	24.61	63
2397	Erivan	do	192	35	Glutinous, spotted.	Good	39.74	61
1596	Fretes	Semi-erect	193	42	Medium starchy.	Fairly good	46.49	63
2398	Galgalos	Spreading	191	37	do	Good	34.94	61
1442	Kharkof	do	193	29	Starchy	Fairly good	38.66	62
2246	Kubanka	Erect	170	36	Glutinous, spotted.	Very good	18.82	63
1593	Marouani	do	185	40	do	do	24.82	62
2235	do	do	184	38	do	do	39.99	62
1597	Medeah	do	196	42	do	do	23.03	62
2989	Minnesota No. 66.	Spreading	203	36	Medium starchy.	Fair	29.00	61
2873	Minnesota No. 163.	do	202	35	do	do	19.71	60
2888	Filipino	Erect	195	38	Very starchy	Very good	29.41	60
1970	Propo	Semi-erect	192	42	Starchy	Fairly good	41.18	63
2991	Purple Straw	do	182	35	do	Fair	44.99	60
2964	Saumur de Mars.	do	190	37	do	Poor	50.92	60
2983	Chiddam	do	191	38	do	do	51.66	61
2235-1	Selection from Marouani.	Erect	178	41	Glutinous, spotted.	Very good	53.76	63
2899	Selection from Chul.	do	152	36	do	do	45.33	62
1743	Sonora	do	186	44	Starchy	Fairly good	34.77	64
1561	Theiss	Spreading	201	36	do	do	19.68	63
1558	Turkey	do	199	30	do	do	32.11	63
2247	Velvet Don	Erect	185	38	Glutinous, spotted.	Very good	23.53	63
2985	Washington Bluestem.	Semi-erect	170	36	Starchy	Fairly good	24.29	61
2404	Yantagbay	Erect	184	37	Glutinous, spotted.	Very good	57.28	64
2096	Yellow Gharnovka.	do	185	39	do	do	24.90	63
2592	[Unnamed]	Spreading	193	40	Starchy	Fairly good	41.99	63

SELECTING VARIETIES FOR CALIFORNIA.

In selecting a variety of wheat which is better adapted to California conditions than the commonly grown varieties a number of matters must be taken into consideration.

CLIMATE AND SOIL.

The climate and soil of the locality in the State where the variety is to be tested are both important factors limiting the distribution of a variety. Some varieties will do well on light soils with a small amount of precipitation, while other varieties require a heavier soil with a larger amount of moisture.

HABIT OF GROWTH.

The effect of the character of the early growth of a variety on its struggle with weeds is very important. (Figs. 6 and 7.) In the valley sections of California, where the temperature does not fall much below freezing during the winter months, varieties of vigorous, upright growth are needed in order that they may keep ahead of and choke out the weeds that start at this time. Varieties with a spreading habit of early growth may be adapted to mountain sections of high elevation, where there is a good deal of snow during the winter months and the temperature falls considerably below the freezing point, thus preventing weed growth until spring.

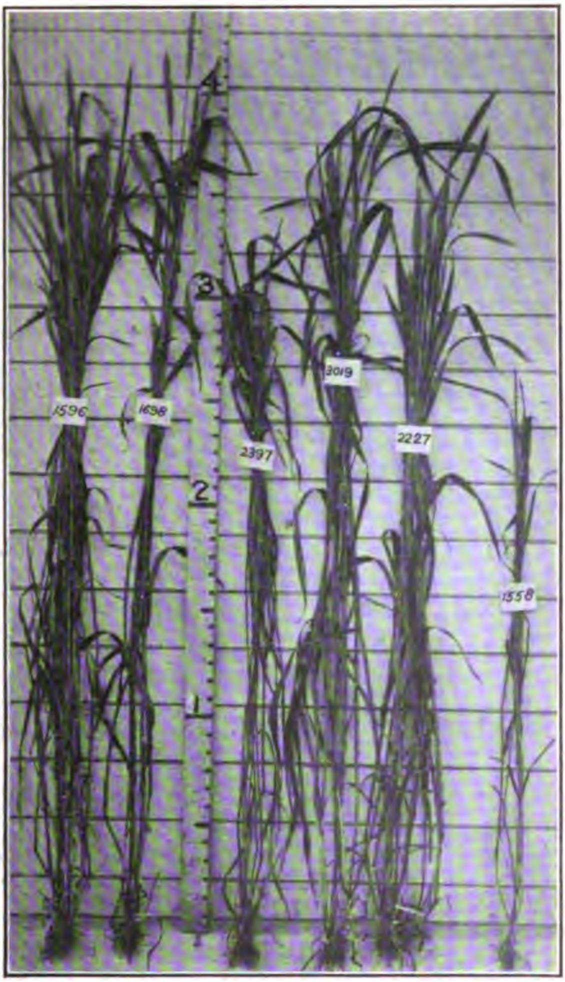

FIG. 6.—Representative plants of six varieties of wheat from uniform plats planted November 21, 1908, at Modesto, Cal., showing their comparative development on May 1, 1909: 1596, Fretes; 1698, Allora; 2397, Erivan; 3019, Australian; 2227, Chul; 1558, Turkey.

NONSHATTERING HABIT.

The nonshattering character of the head of wheat is a very important factor in some sections of California, as heavy windstorms often occur after the grain is ripe and before it is harvested. These winds shatter out a great deal of grain from varieties which have not a very close-fitting chaff. The method of harvesting also has a tendency to shatter out much of the grain where it is not closely held by the chaff, owing to the fact that the crop is often allowed to stand for weeks after it is ripe.

MILLING QUALITY.

The milling quality is perhaps the most important factor to be considered in California. On account of the poor quality of the commonly grown varieties the California millers are unable to make good flour from these wheats when using them alone. Better milling wheat is imported from Kansas and other States of the Middle West to blend with California wheat in the production of flour. From one-third to one-half of the blended wheat is made up of the Turkey variety. It is desired to make unnecessary this importation by the production in California of varieties equally as good. The flour value of wheat is judged by both the quantity and the quality of the product. In order to produce wheat of superior milling quality it is essential that varieties be grown which will give more and better protein to the acre. The quality of the protein depends on the quality of the gluten.

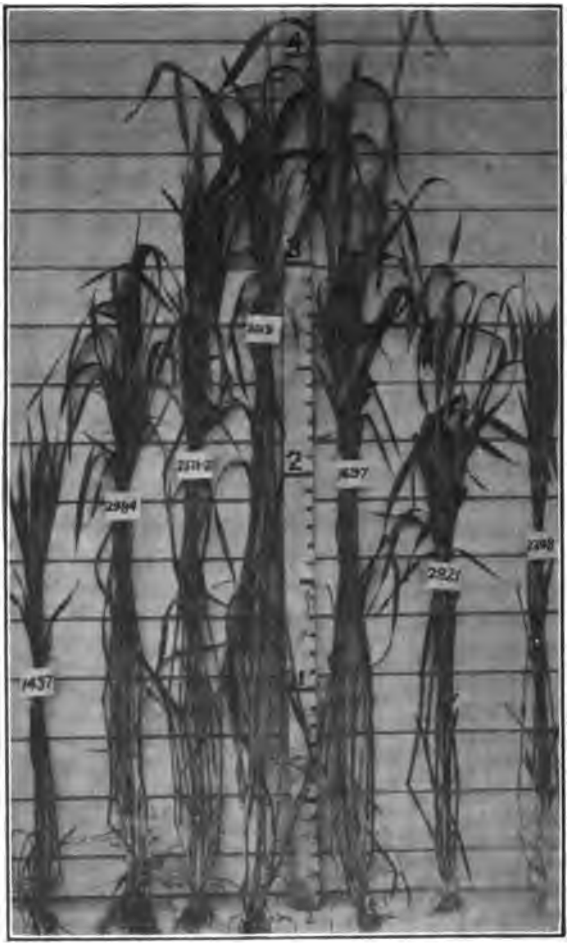

Fig. 7.—Representative plants of six additional varieties of wheat from uniform plats planted November 21, 1908, at Modesto, Cal., showing their comparative development on May 1, 1909: 1437, Crimean; 2984, Saumur de Mars; 2511-2, Abyssinian; 3019, Australian; 1697, Early Baart; 2921, Bolo Blanco; 2398, Galgalos.

OTHER REQUISITES.

The ability of a variety to yield well under proper environment, the possession of a stiff or a weak straw, and the presence or absence of beards are all factors that need no further explanation, but must all be considered in the selection of a variety. Rust resistance is an important factor, especially in the coastal sections of California. Beardless varieties are often desired by the grower, as he may wish, on account of occasional seasonal disadvantages, to cut the crop for hay instead of allowing it to stand for grain. In such a case beardless wheats may be of more value than bearded ones, though this is not an important matter.

SEED IMPROVEMENT BY THE GROWER.

It is very important that the grain growers of California practice better methods of seed selection.

SMALL COMPARED WITH LARGE SEED.

The idea which prevails among some growers that small, light seed will produce as good crops as large, heavy seed is erroneous. In some instances, under very favorable conditions and if sown at the same rate to the acre according to weight, the small, light grains produce as heavy yields as the large, heavy grains, but the grain is of an inferior grade. The reason for the equality in yield to the acre is largely due to the fact that in the case of the seeding of small, light grains there are many more plants to a given area than when it is seeded with an equal weight of large, heavy grains of the same variety.

Heavy, plump grain produces stronger and more vigorous plants than light, shriveled grain. The reason for this is that the plump grain contains a larger amount of food for the very young plant. The light, shriveled grain produces weak plants. This is a fact well understood by all who are endeavoring to improve their crops by careful and practical selection of seed.

It behooves the grain grower, then, to have at his disposal a good fanning mill with which he can grade his seed, blowing out all light, shriveled grain and separating the large grains from the small. Another advantage in the use of the fanning mill is the separation of the weed seed from the wheat.

THE SEED PLAT.

A practical method of improvement of seed, which should be used by every wheat producer in California, is what is known as the seed plat. This method is simple and easily applied. First, select from the general field at ripening time a large quantity of good heads of a single desirable form. Only heads from the best plants should be selected, and they should be from places where the soil is uniform with other parts of the field and not from an especially fertile spot or at the edge of the field. The heads should be thrashed by hand and the seed sown on well-prepared land free from volunteer grain. This crop should be harvested and thrashed separately from the main crop, care being taken that the machinery used is free from all other grains which might cause a mixture. The first portion thrashed should be rejected, as it is most likely to contain such a mixture. The grain from the seed plat should be used, as far as it will go, for the general crop the succeeding year. If there is a considerable acreage it may be necessary to continue the seed plat for a second year in order to obtain sufficient seed for the main crop. In order to effect permanent improvement the grower should make these selections of the best heads every year and sow them on the seed plat as suggested.

TWO NEW VARIETIES OF WHEAT ADAPTED TO CALIFORNIA CONDITIONS.

Of the many new varieties of wheat tested for yield and nitrogen content, the Chul (G. I. No. 2227) and the Fretes (G. I. No. 1596) have proved superior to the White Australian and Club varieties grown in the San Joaquin and Sacramento valleys and are recommended for trial by farmers.

THE CHUL VARIETY.

ORIGIN AND HISTORY.[a]

Chul wheat (fig. 8) was received by the Office of Seed and Plant Introduction, December 1, 1902, from Dzhizak, a town about 100 miles north of Samarkand, Turkestan. It was obtained through the Samarkand representatives of Mr. H. W. Durrschmidt by Mr. E. A. Bessey, of the Bureau of Plant Industry, August 30, 1902. The following notes concerning it were secured by Mr. Bessey:

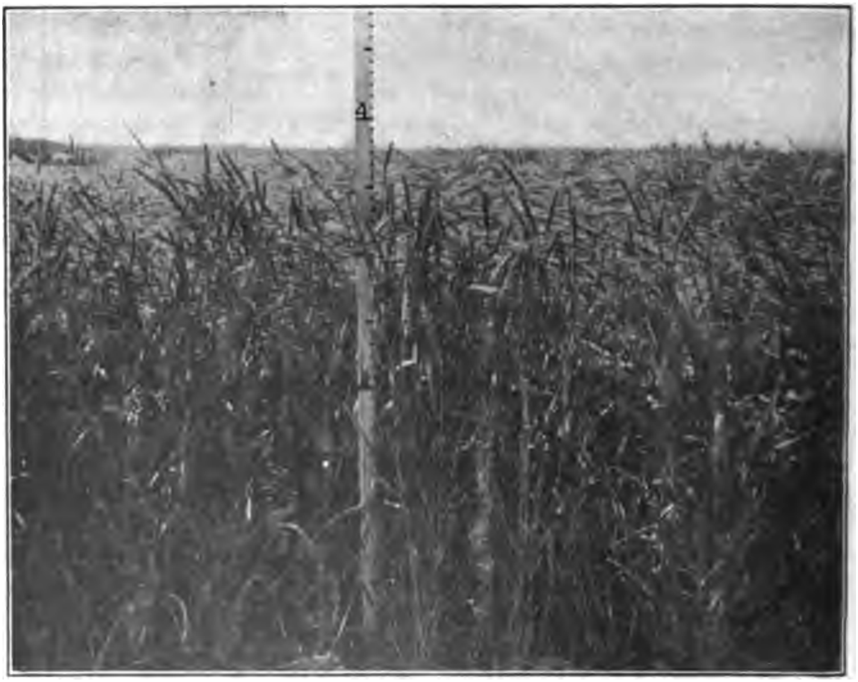

FIG. 8.—Chul wheat (G. I. No. 2227) growing at Modesto, Cal., in 1909. Yield to the acre, 53.33 bushels.

> Chul is grown on the steppes of Russia without irrigation. The grains are hard, but it is not a durum wheat. This variety yields two harvests a year, for it can be

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[a] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, p. 250.

sown as either a winter or spring wheat. If the former, the harvest comes in July; if the latter, the harvest comes in September. If sown in the spring, it is sown just as soon as the snow melts. The spring sowing is most certain to yield a good crop, for the fall sowing must depend upon the rather uncertain snows. This seed, however, is from the fall-sown seed. It is selected from over 1,000 poods offered for sale, and is remarkably clean and free from foreign seeds for this region.

INTRODUCTION INTO CALIFORNIA.

Seed of Chul wheat was first distributed by the United States Department of Agriculture in 1903 to a few farmers in California. Since 1903 small quantities have been sent out from time to time for the purpose of testing its adaptability. In 1904 and 1905 a variety test was commenced in Stanislaus and Sutter counties. This test was in direct charge of an officer of the Department, and has continued up to the present time. A limited distribution of improved seed of California-grown Chul wheat has been made to reliable farmers who are desirous of improving the yield and quality of their crop.

DESCRIPTION.

The Chul is an early, erect, and vigorous variety which may be sown as late as February 15 and mature a good crop. It grows to a height of from 2½ to 4 feet and stools freely. The heads are medium long, tapering, and bearded. This variety has a very close-fitting chaff and does not shatter readily. As originally introduced it contained two forms, the one having white chaff, while the other produces red chaff. The kernels are large, long, and translucent in character. They are harder and more glutinous than those of the White Australian wheat. As originally introduced there were also two types of kernels, the one type being amber in color, the other dark red or reddish amber.

A separation of the red chaff form was made in 1905 at the Department's Plant Introduction Garden at Chico, Cal. Since that time the Department has separated the two forms represented by both colors in the original seed. This has been done by starting with single plants which were each characteristic of the form desired.

YIELDS OBTAINED.

Very promising results have been reported from California to this Department by farmers who have given Chul wheat a trial. In variety tests made by the Department it has made a very favorable showing, excelling the commonly grown varieties in yield to the acre in some sections of the State.

The average yield to the acre of Chul wheat for 1907, 1908, and 1909, as compared with the White Australian, is as follows:

Chul (G. I. No. 2227)	44.5 bushels.
Australian (G. I. No. 3019)	35.9 bushels.

MILLING QUALITY.

The milling quality of Chul wheat is superior to that of either the Club or the White Australian wheat, and for this reason this variety is of much value to the State of California. As previously shown, the common California wheats do not in themselves produce a high grade of flour.

The Department has made milling and baking tests of Chul and White Australian wheats grown at Modesto, Cal., in 1908. The results of this test indicate that Chul wheat produces from 100 pounds of grain about 10 pounds more flour than the Australian, and that it mills very much like Turkey wheat. The flour from the Chul is darker than that from either Australian or Fretes wheat, which in itself indicates that the Chul variety is stronger in gluten.

In the baking test Chul flour required more water to the loaf than that of the Australian variety and produced loaves of fair color and texture.

In August, 1909, the Oakdale Milling Company, Oakdale, Cal., made a milling test of Chul wheat, crop of 1909, grown at Modesto, Cal. This test gave 55 per cent wet gluten for the Chul, while similar tests showed only 10 to 38 per cent in the White Australian. Mr. Haslacher, manager of this company, was very enthusiastic over this variety and anxious that farmers should secure seed.

THE FRETES VARIETY.

ORIGIN AND HISTORY.[a]

Seed of Fretes wheat (fig. 9) was received by the Office of Seed and Plant Introduction of the United States Department of Agriculture on September 26, 1901, from El-Outaya, Constantine, Algeria. It was obtained by Messrs. D. G. Fairchild and C. S. Scofield, who make the following notes on it:

> This variety, sometimes called Freitiss, is one of the few soft wheats grown in Algeria. It is particularly noted for its early maturity and is often extensively planted in the Sahara Desert in seasons when the winter rains occur so late that the durum varieties usually grown would not have time to mature. When planted in November, as it is in Algeria, at the same time with durum varieties, it is said to ripen two months in advance of them. The seed obtained was grown on the rather salty desert sands in the vicinity of El-Outaya, north of Biskra, and watered with somewhat alkaline but still drinkable irrigation water. The variety is said to have originated from a shipment of Russian wheat which was made into Algeria at the time of a famine many years ago. Its early-maturing qualities attracted attention, and it has been cultivated in small quantities by the Arabs ever since. The seed obtained is from the farm of Mr. Charles B. des Places.

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[a] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, p. 151.

DESCRIPTION.

Fretes wheat is an early, erect, vigorous variety and should be sown not later than December 15. It grows to a height of from 3 to 4½ feet and stools well. The heads are of medium length, tapering, and bearded, with white chaff. The chaff of Fretes wheat does not inclose the grain as closely as that of the Chul variety, but still holds the seed fairly well. The kernels are medium large and plump, of medium length, and a reddish-amber color. They are softer than those of Chul wheat. Single-plant selections have been made which are very promising.

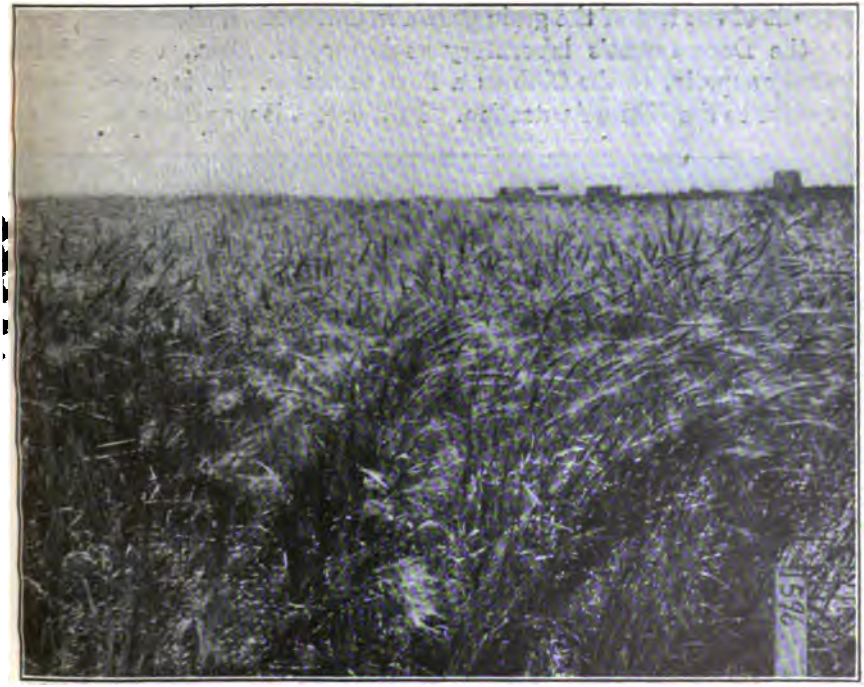

FIG. 9.—Fretes wheat (G. I. No. 1596) growing at Modesto, Cal., in 1909. Yield to the acre, 56 bushels.

YIELDS OBTAINED.

Fretes wheat was distributed by the Department to a few farmers in California as early as 1902, and very good reports on its adaptability have been received. In 1904 and 1905 the Department commenced a variety test of this wheat on the experimental grounds in Sutter and Stanislaus counties. The observations made on the adaptability of this wheat to California conditions indicate that it will produce a larger yield to the acre than either the White Australian or Club wheats and that it is superior as a milling wheat.

The average yield to the acre of Fretes wheat at Modesto, Cal., fo 1907, 1908, and 1909, as compared with the White Australian (fig. 10) is as follows:

Fretes (G. I. No. 1596)	46.5 bushels.
Australian (G. I. No. 3019)	35.9 bushels.

MILLING QUALITY.

Milling tests of this variety have been made by the United Stat Department of Agriculture and by the Oakdale Milling Company. A a result of the test of the grain grown in California during 1908, mad by the Department's laboratory at Fargo, N. Dak., we find thi variety superior to the Club as a flour producer. It is also slightl superior to the White Australian. In this test it was discovered tha

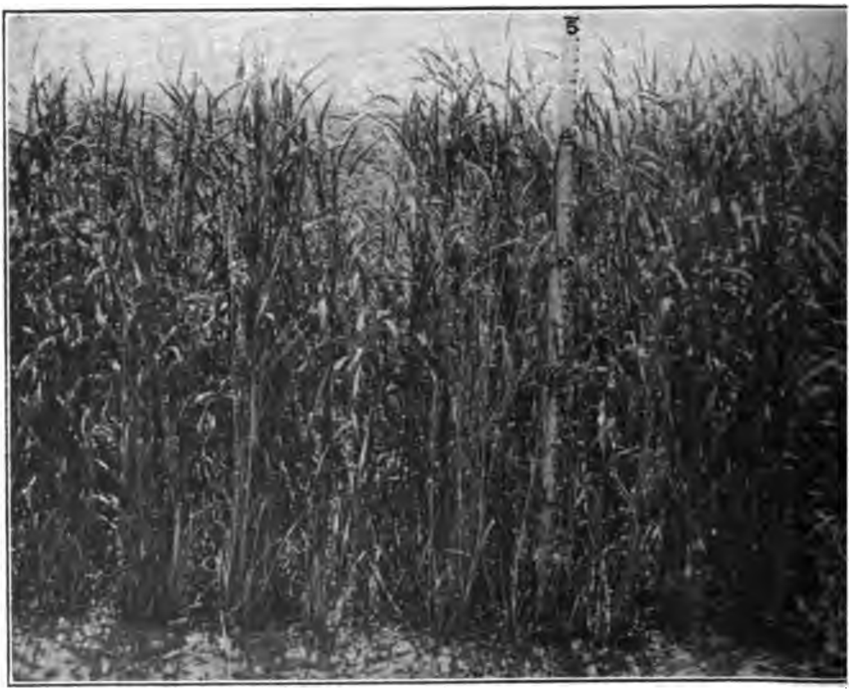

FIG. 10.—White Australian wheat (G. I. No. 3019) growing at Modesto, Cal., in 1909. Yield to the ac 44 bushels.

there was a slight increase in the quantity of flour produced from 10 pounds of the Fretes over that produced from the same quantity Australian wheat. It milled very much like the Australian. A proximately the same quantity of water was required to produce loaf of bread made from this flour as from the Australian. The loav were slightly smaller but heavier than those baked from the Australia The color and texture were fairly good. As with the Chul wheat, milling test of the 1909 crop of the Fretes was made by the Oakdale Milling Company, Oakdale, Cal. This test indicated that the Fretes milled easily. It also possessed a 40 per cent wet-gluten content as compared with the Australian samples received and tested by the company, which contained from 10 to 38 per cent of wet gluten.

PURE SEED OF THE CHUL AND FRETES VARIETIES.

From the foregoing facts there can be little doubt that the improved types of the Chul and Fretes varieties are of great value to California. Much care, however, should be exercised by the growers in securing pure seed.

It is reported that Chul wheat is being grown in quantity by a few farmers in the Sacramento Valley from seed introduced into California by the United States Department of Agriculture in 1903. It is also reported that this wheat is used to good effect in blending with the common wheats in the production of flour. Samples of the 1909 crop, which have been received, show that this wheat is mixed with other varieties. This is probably due to lack of care on the part of growers in keeping the variety pure. This mixture is an inferior grade of seed and is not desirable for the farmer wishing to start with pure seed of the Chul variety.

The Office of Grain Investigations of the Bureau of Plant Industry can usually supply small quantities of pure seed of these and other varieties.

PROTEIN CONTENT AS AFFECTED BY TIME OF SEEDING.

Observations in California indicate that the length of the growing and fruiting periods of a variety of wheat controls, to a considerable degree, the percentage of protein contained. Long growing and fruiting periods produce grains lower in protein content than short growing and fruiting periods. An effort was made during the past year to determine the effect of the length of these periods upon the protein content of the Chul and Fretes varieties sown early and late. The results obtained are given in Table III.

TABLE III.—*Effect of the length of growing and fruiting periods on the protein content of the Chul and Fretes wheat varieties.*

Grain Investigations No.	Variety.	Length of growing period.	Length of fruiting period.	Protein.[a]	Yield to the acre.
		Days.	*Days.*	*Per cent.*	*Bushels.*
2227	Chul	171	46	11.06	53.33
2227	do	151	41	12.43	52.89
1596	Fretes	177	45	10.94	56.00
1596	do	152	40	14.08	45.53

[a] The percentages of protein were obtained by multiplying the percentage of nitrogen by 5.7.

As indicated in Table III, a higher percentage of protein is produced in a short growing and fruiting period than in a long period. The yields of Chul wheat are nearly equal, while there is some difference in those of the Fretes. In order to shorten the periods and produce grain rich in protein, the seeding should be done as late as possible in the fall. The Chul variety is especially adapted to late seeding for the reason that it is a vigorous grower and ripens early. Excellent results have been obtained from the Chul when sown as late as February 25, but usually the seeding should be done between November 15 and December 25. The Fretes seed should be in the ground by December 15. The above dates refer to the time of seeding in the San Joaquin Valley. These wheats may be sown a month later in the Sacramento Valley and still give good results under ordinary conditions.

SUMMARY.

Wheat yields in California are low and the quality poor. Experiments have been conducted to discover the causes and remedies. Two remedies are proposed in this bulletin, namely, better cultivation methods and better varieties.

The cultivation methods commonly practiced by the wheat farmers of California are unsatisfactory. They consist in the continuous cropping of wheat and barley upon soil which receives only a very shallow cultivation.

The farmer removes the plant food from the soil without adding anything to take its place. This is resulting in many localities in a depleted condition of the soil and in unprofitable crops.

When wheat was at first produced, good crops were secured by very shallow plowing, broadcasting the seed, and harrowing it into the soil. Very little attempt was made to secure pure seed or to practice the careful grading of wheat.

Some important changes have taken place, among which are (1) the replacing of the header and stationary thrasher by the combined harvester and (2) the practice of summer-fallowing the land. A reduced size of farms and an increased depth of plowing occur in individual instances.

In many sections of the State there has resulted from the original methods a soil depleted in humus and nitrates and foul with weeds, which fails to produce profitable crops. There are three chief requirements in restoring the production of profitable crops. These are (1) smaller farms, personally supervised; (2) improved methods, including deeper plowing, increasing the humus and nitrates of the soil, and cleaning the land of weeds; and (3) the development of better varieties.

Soil humus and nitrates are easily increased by turning under green-manure crops. Crops proving to be of value as green manure are Canadian field peas and Abruzzes rye. Green-manure crops should not be sown later than December 15. The stubble should be double-disked immediately after the wheat crop is harvested, followed by a shallow plowing as early as possible in the fall. These crops should be turned under during early March before the soil is too dry for deep plowing, which is necessary in order to get the growing peas and rye well under, after which the soil should be harrowed immediately.

The good effect of deep plowing and green manuring is proved in actual experiment by increased yields and profits.

A method of cultivation whereby the land may be cleaned of weeds should be employed.

A large number of wheat varieties have been tested in California in an attempt to find better ones. Factors entering into the selection of varieties for California are the climate and soil of the locality where the variety is to be tested, the habit of growth of the variety, its nonshattering character, milling quality, yield, strength of straw, the presence or absence of beards, and rust resistance.

It is important that grain growers practice better methods of seed selection. The seed should be graded with a fanning mill. A practical method of improvement is the use of what is known as the "seed plat."

The Chul and Fretes wheats are new varieties adapted to California conditions. In some sections of the State these wheats have excelled the commonly grown varieties in yield to the acre.

Milling and baking tests of the Chul and Fretes varieties have been made which indicate that they are superior to Australian and Club wheats in these respects.

Much care should be exercised by the growers in securing pure seed of these wheats.

Observations indicate that the length of the growing and fruiting periods of a variety of wheat controls to a considerable degree the percentage of protein contained. Short growing and fruiting periods produce grain with a high percentage of protein.

The Chul and Fretes varieties are adapted to comparatively late seeding, which is favorable to a high percentage of protein in the grain produced.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 179.

B. T. GALLOWAY, *Chief of Bureau.*

THE FLORIDA VELVET BEAN AND RELATED PLANTS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 26, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 179 of the series of this Bureau the accompanying manuscript, entitled "The Florida Velvet Bean and Related Plants," prepared by Messrs. C. V. Piper, Agrostologist in Charge, and S. M. Tracy, Special Agent, Forage-Crop Investigations.

This paper points out an interesting example of the confusion that exists in the botany of the cultivated plants, which has in this particular case brought about the neglect of a number of valuable sorts related to the Florida velvet bean. Two of these species possess decided elements of superiority and will without doubt result in extending far to the northward the culture of this crop, as well as in greatly increasing its importance. This paper discusses nine of the species that have been studied, but is to be considered a preliminary rather than an exhaustive publication.

The authors desire to acknowledge the helpful suggestions and assistance rendered them by Mr. W. F. Wight, Botanist, of this Bureau.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—558.

THE FLORIDA VELVET BEAN AND RELATED PLANTS.

INTRODUCTION.

For about fifty years the Florida velvet bean has been known in Florida, and in the last twenty years has become of increasing agricultural importance. Its early history has been told by Mrs. K. S. Bort in Bulletin No. 141, Part III, of the Bureau of Plant Industry.

The Florida velvet bean is principally grown on account of its extreme vigor and the large quantity of pods which it produces per acre. The plants are nearly always utilized by pasturing to stock, cattle being turned into the fields in November and finishing on the velvet bean in good condition for marketing.

The Florida velvet bean is a long-season crop, and even in Florida has to be planted early in the spring in order to mature its seed. On this account an earlier variety has long been a desideratum, especially if along with earliness can be secured a greater production of seed per acre. For various reasons the fact that there are other kinds of Stizolobium closely related to the Florida velvet bean has been overlooked by American agronomists, though at least three such species from India and Java were long ago described. Apparently none of these, however, were introduced for trial in Florida until 1907.

In September, 1906, there were received from Dr. J. W. Hart, Piracicaba, Brazil, seeds of a species of Stizolobium (S. P. I. No. 19181) which differed from the Florida velvet bean in having coal-black, shining seeds, and in February, 1907, another species, with white seeds, was received from Mr. W. S. Lyon, Manila, P. I., under the name of *Mucuna lyonii* Merrill. These two lots were grown in 1907 and since. After their receipt it seemed to be wise to endeavor to get together all of the other species of this genus in the hope of finding varieties that would prove earlier or otherwise more valuable than the Florida velvet bean. In the three years during which this effort has been made, with the assistance of the Office of Foreign Seed and Plant Introduction, twenty sorts distinct at least as to seed characters have been obtained. Not only have these varieties indicated that there are greater possibilities in this group of plants than had been supposed, but an exceedingly interesting botanical problem has been disclosed, as there are clearly more species than had been recognized by botanists.

Until the publication of the paper previously mentioned,[a] the Florida velvet bean had been known in this country under the name of *Mucuna utilis*. Mrs. Bort showed clearly that it could not be the plant originally described under that name, nor could it be identified with any other described species. On this account she named and described the plant as a new species, *Stizolobium deeringianum*. She also emphasized the fact that the Florida velvet bean and allied plants constitute a distinct genus from Mucuna, pointing out that the genus Mucuna consists of perennial plants with woody stems and with a band-like hilum that extends two-thirds of the way around the seed, or more, while the genus Stizolobium[b] consists of plants essentially annual, with an oblong-crateriform hilum to the seed. She further stated that Mucuna in germination is hypogeous, while Stizolobium is epigeous. This last statement is incorrect, as both are hypogeous. There is a pronounced difference, however, in the germination. In Stizolobium the first leaves above the cotyledons are a pair of petioled leaves having solitary cordate leaflets, which immediately are followed by the typical alternate, trifoliate leaves of the plant. In Mucuna, on the contrary, the initial leaves are all alternate, very much reduced, and scale-like. These differences are well shown in Plate I, where the germination of *Mucuna keyensis* is contrasted with that of *Stizolobium hassjoo*.

Of the 20 forms of Stizolobium obtained, 10 have been grown to maturity for one year or more in the field, and several others in the greenhouse. The field work has been conducted principally at Biloxi, Miss., and in cooperation with the Florida Agricultural Experiment Station at Gainesville, Fla. In addition, large quantities of seeds of the Lyon bean (S. P. I. No. 19979) and considerable quantities of the fleshy-pod bean (S. P. I. No. 21094) and of the Mauritius or Bengal bean (S. P. I. No. 21300) have been distributed for field testing.

The characters by which the different species of Stizolobium are distinguished are principally in the pods and seeds; otherwise the species are much alike both in habit and foliage. Slight differences occur in the leaves and flowers, which, however, are not conspicuous. It is probably due to the fact that most herbarium material does not contain mature pods that the distinctness of the species has not before

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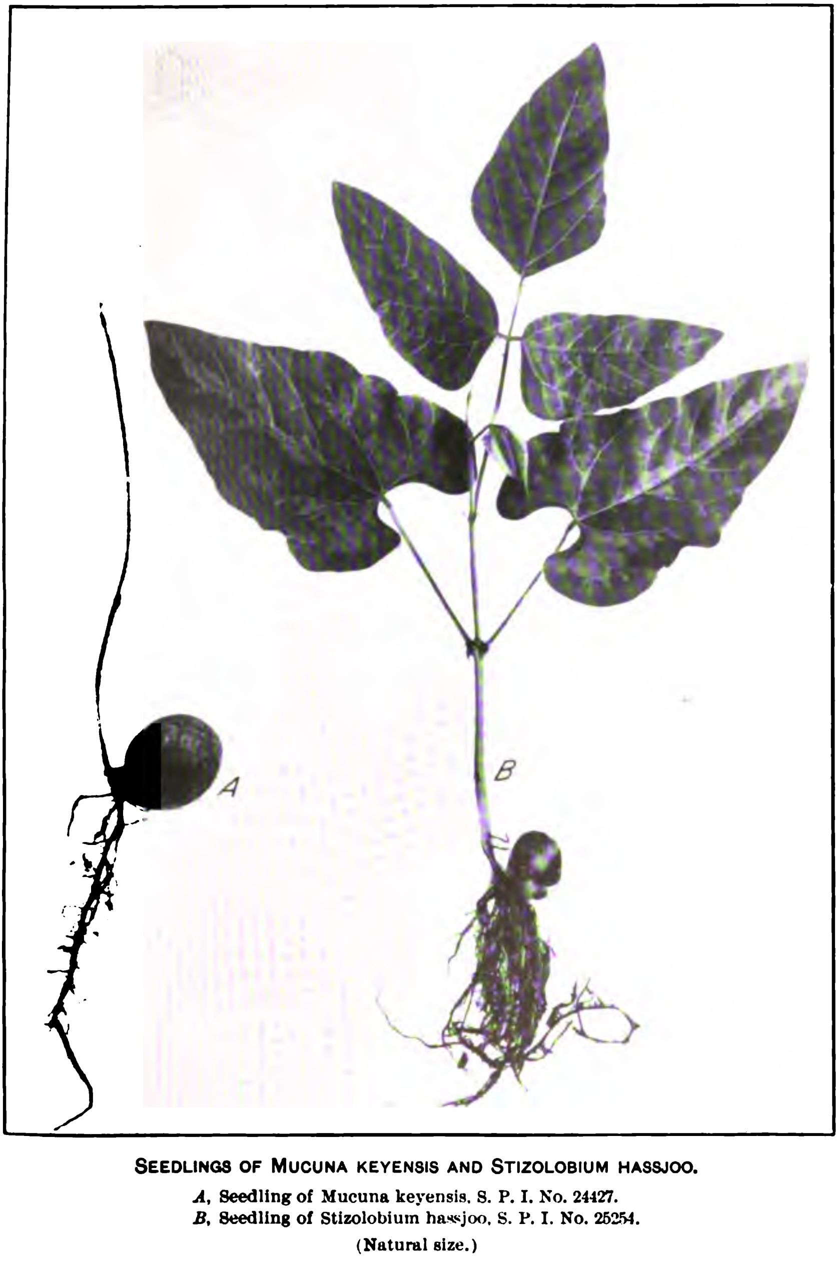
[a] Bulletin 141, pt. 3, Bureau of Plant Industry, 1909.

[b] The genus Stizolobium was first published by Patrick Browne (The Civil and Natural History of Jamaica, 1756, p. 290) and based upon the species now known as *Stizolobium pruriens*, the common cowitch. The seed characters by which Stizolobium is distinguished from Mucuna have been clearly pointed out by Prain (Journal of the Asiatic Society of Bengal, n. s., vol. 66, 1897, p. 404.)



SEEDLINGS OF MUCUNA KEYENSIS AND STIZOLOBIUM HASSJOO.

A, Seedling of Mucuna keyensis. S. P. I. No. 24427.
B, Seedling of Stizolobium hassjoo. S. P. I. No. 25254.

(Natural size.)

been recognized by botanists. There is also a considerable range as respects the life period of the species, some being much earlier than the Florida velvet bean and others much later.

The pod differences are displayed in differences of size, of shape, of ridges on the valves, and especially in the character of the pubescence. The latter character in the various forms is such that it seems impossible to refer them to a single species, as in no genus of legumes known to us do we find differences of this kind in agricultural varieties known to be such. Furthermore, these plants never seem to have been cultivated sufficiently to give rise to series of varieties such as are found in most cultivated legumes. A number of the species have been cultivated to a slight extent by the Hindus. Another species, *Stizolobium velutinum* (Hassk.) (*Mucuna velutina* Hassk.), seems to be more or less extensively cultivated in Java. In this species Hasskarl mentions six varieties differing in seed characters, but calls attention to no pod differences. The evidence at hand does not yet justify us in deciding whether all of these are really garden varieties or distinct species, but the latter conclusion best coincides with the facts thus far ascertained. Still another species, *Stizolobium hassjoo*, is said to be extensively cultivated in Yezo, the north island of Japan. This last is by far the earliest form yet obtained and will doubtless mature its seed as far north as Tennessee and North Carolina. From a single season's experience it seems to possess unusual merit and will probably come into extensive cultivation, especially for growing with corn.

Detailed notes setting forth the present knowledge of the different forms is given in connection with each species.

GENERAL CHARACTER OF THE GENUS STIZOLOBIUM.

All of the stizolobiums thus far grown are large, annual, much-branched, twining herbs, the stems twining in an opposite direction from the hands of a watch; leaves trifoliate, with large membranaceous leaflets shorter than the petiole; leaflets ovate, the lateral ones oblique, all mucronate, and attached by short, fleshy, very pubescent petiolules; stipules small and lanceolate; stipels bristle-like; flowers in pendent, usually long racemes, the flowers mostly in groups of three; mature pods black, pubescent, marked with one or more longitudinal ridges, or these rarely obscure or wanting.

From an economic standpoint, the species of Stizolobium may be divided into two groups, those which have abundant long stinging hairs on the pods and those which have few or no stinging hairs. The former also have stinging hairs on the calyx. In the former category are to be placed *Stizolobium pruriens* (L.) Medic. (*Dolichos pruriens* L.), the cowhage or cowitch, the type of the genus which is native to the East Indies but which also occurs now in Jamaica and other West Indian Islands, probably as an introduction; *Stizolobium pruritum* (*Mucuna prurita* Hook. in Wight and Arnott, Prodromus Floræ Indiæ Peninsulæ Orientalis, 1834, vol. 1, p. 255); and *Stizolobium hirsutum* (W. and A.) Kuntze (*Mucuna hirsuta* Wight and Arnott, op. cit., p. 254), both of the latter native to India. Only one of these species with stinging hairs on the pods has matured in our trials, namely, S. P. I. No. 25263, *Stizolobium pruriens* (?). None of these species with stinging hairs can be utilized as forage crops, but they have been grown with the idea of ascertaining their relationship to the more valuable forms.

All of the stizolobiums possess something in the juice, especially in the green pods, which rapidly turns black on exposure to air. This substance blackens the hands and clothing of workmen cutting velvet beans for hay, which is occasionally done. It also causes the dried flowers and pods to become black, and does the same to the seeds of white-seeded varieties, especially if gathered too green o where they press upon each other.

Botanical descriptions and economic notes concerning nine species are presented in this publication.

ANALYTICAL KEY TO THE SPECIES.

- Pods velvety with black pubescence.
  - Seeds marbled, rarely white, thick, subglobose; pods 2.5 to 3 inches long, nearl as thick as broad.. *deeringianum*
  - Seeds black, oblong, somewhat flattened; pods flattened, 4 to 4½ inches long, *capitatum*
- Pods pubescent, but the pubescence not black or velvety.
  - Pubescence dense, erect or nearly so, not appressed.
    - Seeds dull black with faint rusty markings; pubescence of pods tawny. *util*
    - Seeds ash colored; pubescence of pods whitish.................. *cinereum*
  - Pubescence white, appressed.
    - Flowers white; leaf surface undulate; seeds ash colored........... *niveum*
    - Flowers purple; leaf surface plane.
      - Pod valves with the principal ridge prominent, but secondary ridge rarely more than one.
        - Pubescence on pods rather coarse and long; leaflets 3 to 5 inche long, rather thick; seeds ash colored.................... *hassjo*
        - Pubescence very fine; leaflets larger and thinner; seeds shinin black.. *aterrimum*
      - Pod valves with a well-developed principal ridge and two or more se ondary ridges; pubescence soft.
        - Seeds flattened, white with black or gray spots; pods large, ve fleshy when green, 5 to 7 inches long; valves with 3 to 5 seconda ridges; pubescence very sparse.................... *pachylobium*

STIZOLOBIUM DEERINGIANUM.

Stizolobium deeringianum Bort.[a] Florida velvet bean. (Pl. II, *B*.)

An annual, herbaceous, climbing vine, sometimes 20 meters in length when growing on supports, and even on the ground attaining a length of from 2 to 6 meters, bearing long, pendent racemes of purple flowers which produce dark, velvety pods 5 or 6 centimeters long. Stems rather slender, terete, sparsely pubescent with white, appressed hairs, especially on the ridges. Petioles equaling or exceeding the leaflets, pubescent like the stem, and continued for 2 to 4 centimeters beyond the lateral leaflets; stipules subulate, pubescent, about 1 centimeter long; stipels similar but smaller; petiolules about 5 millimeters long, stout, very pubescent. Leaflets rhomboid-ovate, the lateral ones oblique, membranaceous, acuminate-cuspidate, 5 to 15 centimeters long, about half as broad, sparsely pubescent above, especially on the veins, more densely pubescent beneath, the white hairs closely appressed. Inflorescence a raceme or thyrsus 15 to 30 centimeters long, pendent, bearing 5 to 30 flowers, usually about 12; rachis like the stem, but more pubescent; flowers borne singly or in twos or threes on short lateral branchlets. Bracts lanceolate-subulate, very pubescent, early fugacious. Calyx pubescent within and without with short, white, appressed hairs, 2 lipped, the upper lip broadly triangular, the lower lip 3 cleft, the lobes triangular-subulate, the middle one longest; stinging hairs absent. Corolla dark purple, 3 to 4 centimeters long; standard less than half the length of the keel, darker than the rest of the flower; wings slightly shorter than the keel, rather broad, oblanceolate-oblong, obtuse; keel straight to near the tip, where it curves sharply upward, the tip firm and acute; anthers of two sorts, alternately long and short, the latter on much broader filaments; ovary linear, pubescent; style filiform, pubescent nearly to the tip; stigma small. Pods when mature 5 to 6 centimeters long, turgid, densely covered with a soft, nearly black, velvety pubescence without stinging hairs; valves with 1 or 2 or sometimes 3 obscure longitudinal ridges. Seeds 3 to 5 in each pod, subglobose, marbled and speckled with brown or black, and sometimes both, on ash-gray ground color (though pure gray and, it is said, pure black occur rarely), 1 to 1.5 centimeters in diameter. Hilum white, oblong-crateriform, less than one-half the length of the seed.

The leaflets of this species are abruptly mucronate from a usually obtuse apex.

This is the well-known species which has been so long cultivated in Florida. Its importance in late years has grown rapidly, and it is now much more cultivated than ever before. The principal objection to it is the long season required for maturing, which has in a large measure militated against its cultivation farther north. It will, however, make a very large growth of vines as far north as Virginia and Kentucky, but rarely matures its seed north of Florida. It is not well adapted as a hay plant on account of its extreme vininess, and where it does not produce pods is of only limited usefulness. Like all of the stizolobiums it is absolutely immune to the wilt which affects so many other legumes and also to root-knot caused by nematodes. In all of the time this plant has been under cultivation in Florida the only variant produced is one having white or nearly white seeds, apparently being identical in all other respects with the ordinary form having mottled seeds.

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[a] Bulletin 141, pt. 3, Bureau of Plant Industry, 1909, p. 31.

The original source of this species has never yet been determined, though in all probability it comes from southern Asia or some island of the Malay Archipelago. It has been widely distributed throughout the world by the United States Department of Agriculture. Seed which is undoubtedly the progeny of such distributions has been obtained from Saigon, Cochin China (S. P. I. No. 25261), and also from Poona, India (S. P. I. No. 25715). On account of the wide distribution which has been made of the seed of this species, it will be rather difficult to ascertain its exact place of nativity, which can probably be determined only by finding the plant growing under conditions where it is undoubtedly wild.

STIZOLOBIUM CAPITATUM.

Stizolobium capitatum (Roxburgh) Kuntze. (Pl. II, *A.*)

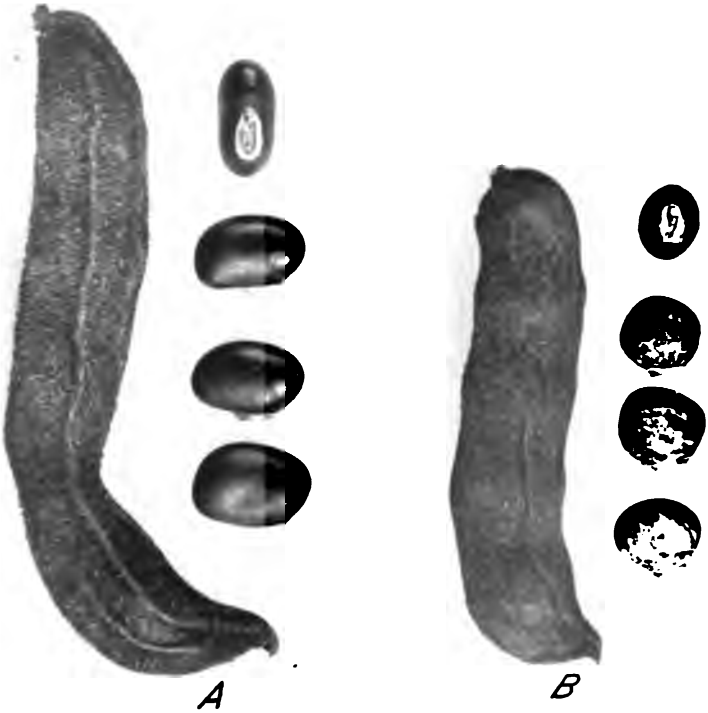
Carpopogon capitatum Roxburgh, Flora Indica, 1832, vol. 3, p. 284.

Mucuna capitata Wight and Arnott, Prodromus Floræ Peninsulæ Indiæ Orientalis, 1834, p. 255.

Roxburgh's original description is as follows:

> Annual, twining. Heads axillary, subsessile. Legumes armed with soft velvet-like down.
>
> *Teling. Soorootoo.*
>
> This I have only found in a cultivated state, and that during the cold season, in the gardens of the natives. It is an annual.
>
> Stem herbaceous, twining, branchy, running to an extent of 10 to 12 feet, if supported; young shoots slightly downy. Leaves ternate. Leaflets equal in size, the exterior ones ovate, about 3 inches long and 2 broad, the lateral ones obliquely cordate; all are entire and obtuse, above smooth, a little downy underneath. Stipules of the petioles axillary, short, many flowered. Bracts, flowers, stamens, and pistil as in *C. pruriens.* Legumes cylindric, depending, a little curved, about as thick as the forefinger or thumb, and about 6 inches long, covered with soft, velvet-like down; when ripe wrinkled longitudinally. Seeds five or six, of the size of a small garden bean, smooth, shining, black.
>
> The young pods like those of *Dolichos lignosus* and *lablab* are used by the natives in their curries, after rubbing off the down that covers them.

Pods 9 to 10 cm. long, about 1½ cm. wide, strongly falcate, much compressed, mostly four seeded; valves with a strong central ridge extending from near the base to the tip, a secondary ridge usually present extending for the upper third; pubescence identical with that of *Stizolobium deeringianum*, dense, soft, nearly black, the larger hairs tipped with white; seeds oblong, glossy, black, with or without faint brownish markings, 8 by 15 mm., the white hilum 5 mm. long.



MATURE PODS AND SEEDS OF STIZOLOBIUM CAPITATUM AND STIZOLOBIUM DEERINGIANUM.

A, Pod and seeds of Stizolobium capitatum (seeds, black), S. P. I. No. 22464-A.
B, Pod and seeds of Stizolobium deeringianum, S. P. I. No. 22339.

(Natural size.)

Seed (S. P. I. No. 25120–A) representing this species was obtained from Maj. A. T. Gage, superintendent of the Royal Botanical Garden, Calcutta, British India. This seed was mixed with S. P. I. No. 25120, *Stizolobium utile*, from the same place. At Gainesville, Fla., this same species was mixed with S. P. I. No. 22464, *Stizolobium utile*, obtained through Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India, under the name of *Mucuna capitata*. As the seeds of these two species are much alike, the mixture was in each case probably accidental.

This species is the only one having pod pubescence of the type found on the Florida velvet bean, but the pods and seeds are very different. At Biloxi, Miss., and Gainesville, Fla., it matures its pods in about the same length of time as the Florida velvet bean, and probably is of about the same agronomic value.

Later botanical writers have made various comments on Roxburgh's species. Wight and Arnott (Prodromus Floræ Peninsulæ Indiæ Orientalis, 1834, p. 255) quote the herbarium name of Roxburgh, *Dolichos soorootoo*, from an unpublished drawing in the herbarium at Calcutta and also identify the plant questionably with Rumphius's *Cacara nigra*, Plate 138, published in the Herbarium Amboinense. The flowers as indicated on Rumphius's plate are very different from those of any Stizolobium, while the pods resemble closely those of *Pachyrhizus angulatus*. The drawing of the seed, however, indicates a typical Stizolobium. We are unable satisfactorily to identify this plate. Wight and Arnott also state that they have examined specimens collected by Klein, obtained from the Missionaries' Garden. Baker, in Hooker (Flora of British India, vol. 2, p. 187), also refers *Mucuna velutina* Hassk. to this species, a reference which we consider erroneous. A similar reference is also made by Miquel (Flora van Nederlandsch Indië, vol. 1, p. 212). Miquel also refers with doubt to this species the plant described by Rumphius in Herbarium Amboinense as *Cacara nigra*. In this he apparently follows Wight and Arnott.

There could seem to be little doubt regarding the identity of this species as based on Roxburgh's ample description and from the further fact that this plant has been received from Calcutta, the type locality. It does not seem likely that Roxburgh's original plant is *Stizolobium utile*, as the pubescence on the pods of that could scarcely be called velvety. The species is perfectly distinct in its pod characters, in which respect it can only be associated with the Florida velvet bean, which has pods of very different shape and seeds of different shape and color.

STIZOLOBIUM UTILE.

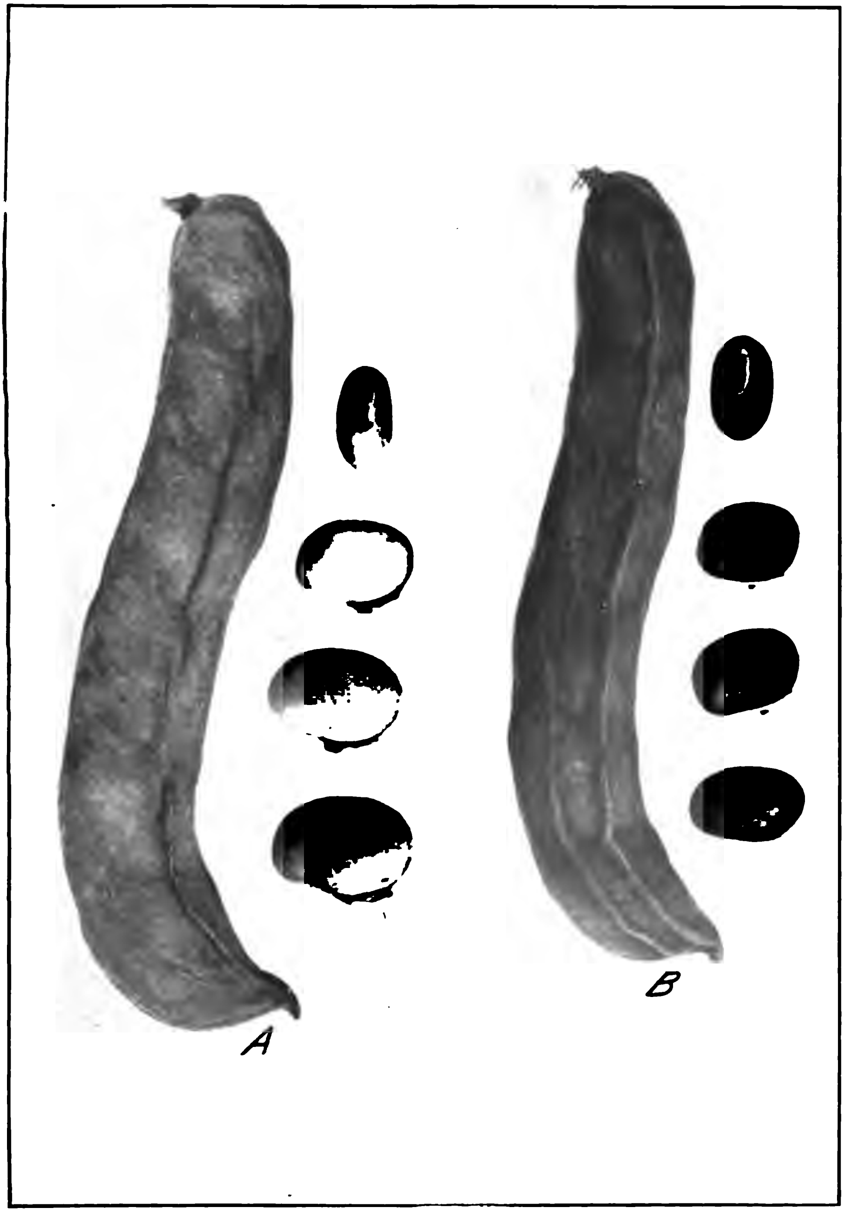
Stizolobium utile (Wall.) n. comb. (Pl. III, *B*).
Mucuna utilis Wall. (Wight, Icones Plantorum Indiæ Orientalis, 1840, vol. 2, p. 280).

Wight publishes an excellent plate of this plant, which has been reproduced in Bulletin No. 141 of the Bureau of Plant Industry, page 28. The only description given by Wight is as follows:

> *Mucuna utilis* (Wall. MSS.). The principal difference of this species, if indeed a species, and *M. prurita* consists in the hairs of its legumes being appressed and almost silky, not erect, rigid, and stinging. In all other respects they sufficiently agree. The flowers in both are purple. The greater size of this is probably attributable to cultivation, in which state only it is known.

Voigt (Hortus Suburbanus Calcuttensis, 1845, p. 235) identifies the plant with "the variety extensively cultivated in the Mauritius and Van Diemen's Land as a table vegetable and also as a fodder for cattle." This plant is the variety with black, shiny seeds commonly known as Mauritius bean. Voigt also gives the name "Pois noir de Bourbon." Cordemoy (Flore de l'Ile de la Reunion, 1895, p. 393) accepts this identification. This author states that the plant on the island of Reunion is known under the name of "Pois mascate." He also gives a detailed description of the plant, which he states was imported into Reunion to serve for breeding purposes, but is now naturalized. We should be inclined to accept this identification if it were not for two facts. First, Wallich's figure indicates more pubescence on the pod than occurs in the Mauritius bean and the pubescence is not closely appressed; secondly, we have obtained from Maj. A. T. Gage, superintendent of the Botanic Garden at Calcutta, seeds of two species of Stizolobium now being grown in the garden at Calcutta. One of these is *Stizolobium capitatum*, already described; the other is the species which we feel confident is the same plant that Wallich has figured. It is very different from the Mauritius bean in that the pod is densely covered with tawny pubescence which is not appressed. The following is a detailed description:

> Stems stout, growing 30 to 50 feet long, striate and furrowed, pubescent with fine retrorse hairs; leaflets plane, ovate, 5 to 8 inches long, mostly obtuse, mucronate, puberulent on both sides with fine appressed hairs; racemes 9 to 15 inches long; calyx saccate, pubescent without and within, with fine white appressed hairs, the upper lobe triangular, blunt or notched, the lower lobe one-half longer than the lateral lobes; corolla dark purple, 1½ inches long, the wings broad; ovary densely pubescent with white and purple hairs; pods flattened, 3½ to 4½ inches long, densely pubescent with short erect or ascending tawny hairs with a few purple ones interspersed; lateral ridge strong, more or less broken, extending nearly the length of the valves; seeds oblong, rather thick, 12 to 14 mm. long, dull black, faintly marked with brown flecks, the veins invisible.



MATURE PODS AND SEEDS OF STIZOLOBIUM CINEREUM AND STIZOLOBIUM UTILE.

A, Pod and seeds of Stizolobium cinereum, S. P. I. No. 22463.
B, Pod and seeds of Stizolobium utile (seeds, dull black), S. P. I. No. 22464.

(Natural size.)

This is S. P. I. No. 25120, obtained from Maj. A. T. Gage, superintendent of the Botanic Garden at Calcutta, British India. Identical with it is S. P. I. No. 22464, from Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India.

This species has been grown for two seasons at Biloxi, Miss., and Gainesville, Fla. It matures with the Florida velvet bean and is about as productive. The pubescence on the pods, however, is rather harsh, rubs off easily, and is irritating to the skin. On this account it will doubtless not be found desirable for cultivation.

STIZOLOBIUM CINEREUM.

Stizolobium cinereum n. sp. Ashy-pod bean. (Pl. III, *A*.)

Stems stout, growing 30 to 50 feet long, furrowed, covered with a fine, harsh pubescence, the hairs not retrorse; leaflets plane, broadly ovate, mostly obtuse, mucronate, 5 to 8 inches long, pubescent on both sides with appressed white hairs, especially beneath; racemes 9 to 15 inches long; calyx saccate, silky with white appressed hairs without, less so within; corolla dark purple, 1¼ inches long; pods flattened, 4 to 4½ inches long, densely pubescent with short erect or ascending white hairs; median ridge prominent, complete, the secondary irregular, varying from continuous to broken or sometimes wanting; seeds oblong, ash colored, the ends often black, veiny, about 15 mm. long.

This species has been grown for two seasons at Biloxi, Miss., and Gainesville, Fla. It matures with the Florida velvet bean, but is no more prolific and the hairs are irritating.

This is S. P. I. No. 22463, from Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India.

STIZOLOBIUM NIVEUM.

Stizolobium niveum (Roxburgh) Kuntze. Lyon bean. (Pl. IV, *A*.)

Carpopogon niveum Roxburgh (Flora Indica, 1832, vol. 3, p. 285).

Mucuna nivea Wight and Arnott (Prodromus Floræ Indiæ Peninsulæ Orientalis, 1834, p. 255).

Mucuna lyoni Merrill (Philippine Journal of Science, Supplement 1, 1906, p. 197).

Roxburgh's original description is as follows:

> Annual, twining. Racemes pendulous. Legumes from six to eight seeded, while young downy; when old destitute of down and wrinkled.
>
> Bengal-Khamach.
>
> Like *Carpopogon capitatum*, I have only found this in a cultivated state, and even then very uncommon, having seen it but in one or two gardens near Calcutta; however, if it is not indigenous in Bengal, it must have been long known to the natives, not only on account of their having a vernacular name for it, but because it is eaten by them, as a Hindoo requires a long and intimate acquaintance with any article before he makes it a part of his diet. Potatoes they must have known fifty years or more before they began to admit them at their tables.

> Be that as it may, the plant is cultivated during the cold season, when it blossoms and produces fruit in great abundance.
>
> Root ramous, generally annual, though in some soils it lasts longer. Stem twining to an extent of some fathoms, very ramous and thick, but of a spongy, succulent nature, young shoots a little villous. Leaves ternate. Leaflets entire, the pair nearly semicordate, the terminal one rhomboidal; all have short acute points and are nearly equal in size, of a soft delicate texture and slightly villous on both sides; from 4 to 10 inches long. Petioles round, slightly villous, from 6 to 12 inches long. Stipules lanceolate. Racemes axillary, solitary, pendulous, often as long or even longer than the leaves, bearing numerous, three-fold, pendulous, very large white flowers. Bracts fourfold, a common one to each tubercle of the racemes, on which the three flowers are inserted, and one to each of the proper pedicels, all are caducous, nearly lanceolate, and villous. Calyx four parted. The upper division broad and emarginate; the lower one narrowest and more lengthened than the lateral pair. Corol papilionaceous. Banner cordate, incumbent on the wings and keel, and about half their length. Wings oblong, with a remarkable callous gland near the base of each. Keel one petalled, linear, length of the wings, with a sharp, rigid, incurved point. Nectary a crenulate gland round the insertion of the germ. Filaments one and nine, alternately clavate and filiform, with long linear, subsagittate anthers on the slender filaments, and short-ovate ones on the clavate ones. Germ hairy. Style slender and villous. Stigma small. Legume linear, about 6 inches long, curved a little like an italic *S* when ripe, black, destitute of down, and longitudinally wrinkled. Seeds generally from six to eight, oval, smooth, ash colored, and separated by thin partitions.
>
> By removing the exterior velvet-like skin of the large, fleshy, tender legumes, they are when dressed, like French beans (*Phaseolus vulgaris*), a most excellent vegetable for our tables, and the full-grown beans are scarcely inferior to the large garden beans of Europe.

We identify as this species S. P. I. No. 24936, obtained through Mr. C. Drieberg, of the Ceylon Agricultural Society, Colombo, Ceylon, which at Biloxi, Miss., and Gainesville, Fla., proved indistinguishable from *Mucuna lyonii* (S. P. I. No. 19979) obtained from the Philippines. The original specimens of *Mucuna lyonii* came from Pampanga Province, Luzon, there called "Sabual." This is the only species obtained by us with ash-colored seeds that has white flowers. Wight and Arnott,[a] in discussing *Mucuna capitata*, comment as follows:

> M. niveum, D. C. (*Carpopogon niveum*, Roxb. in East India Company, mus. tab. 1601) is a species very closely allied, but differs by the long drooping racemes and the legumes when ripe, entirely free from pubescence; it likewise is only known as a cultivated plant.

Watt's Dictionary of the Economic Products of India, 1891, vol. 5, p. 285, comments as follows:

> Met with in Burma and Bengal, perhaps only a cultivated variety of *Mucuna pruriens*.
>
> Cultivated during the cold season for the sake of its abundant and useful fruit. The large, fleshy, tender legumes have long been known and valued as a vegetable by the Hindus, and, according to Roxburgh, are, when dressed, like French beans, a most excellent vegetable for European tables.

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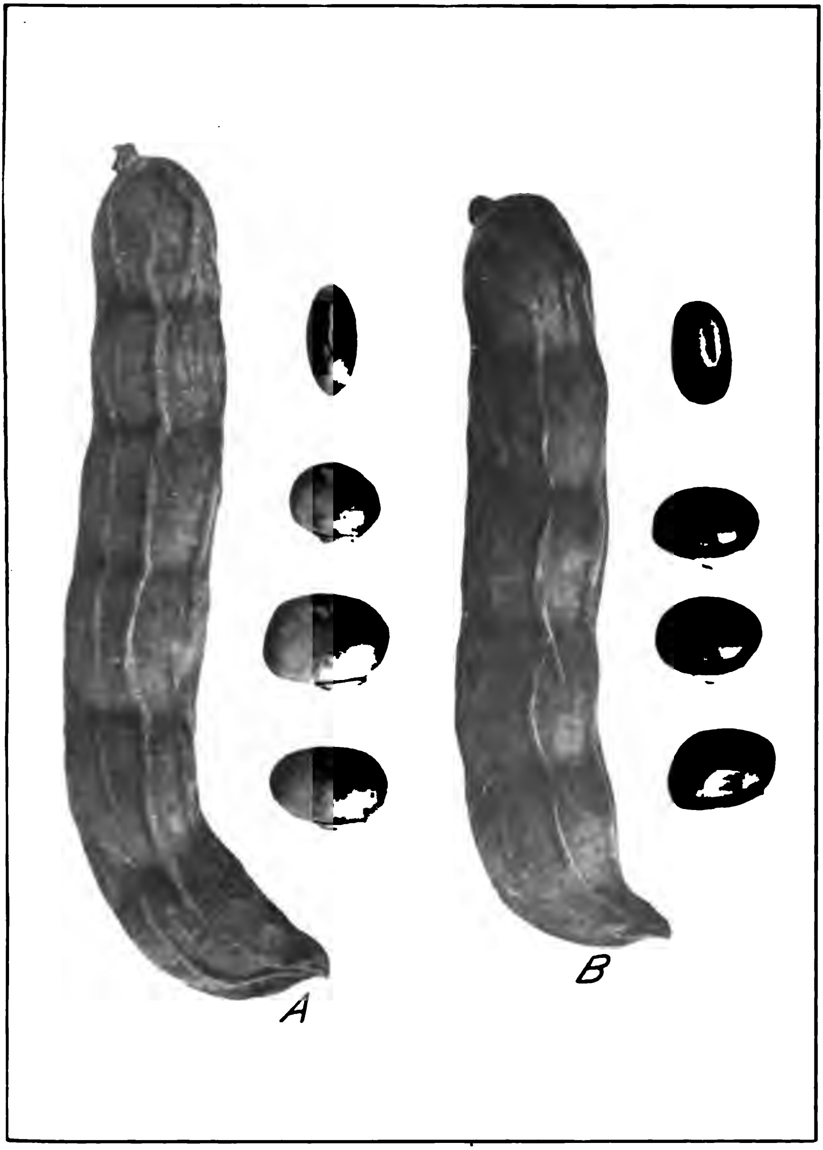
[a] Op. cit., p. 255.



MATURE PODS AND SEEDS OF STIZOLOBIUM NIVEUM AND STIZOLOBIUM ATERRIMUM.

A, Pod and seeds of Stizolobium niveum, S. P. I. No. 19979.
B, Pod and seeds of Stizolobium aterrimum (seeds, shining black), S. P. I. No. 21300.

(Natural size.)

Watt also states that the vernacular names in use in Bengal are "Khamach" and "Alkushi." Firminger (Manual of Gardening for India, p. 133) says: "To me the beans seem to partake rather of the agreeable flavor of the Lima bean, and afford a very nice dish during the latter end of the rain season." Baker in Hooker (Flora of British India, vol. 2, p. 188) quotes *Mucuna nigra* Ham. (in Wall. Cat. 5617) as a synonym, but neither description nor citation accompanies the publication of that name.

The Lyon bean has now been cultivated in Florida and other Southern States for three years. It requires about the same length of time to mature as the Florida velvet bean, or is perhaps slightly earlier. It is, however, much more prolific in seed production and is therefore likely to come into prominent use. Besides its greater productivity it has the advantage over the Florida velvet bean of being wholly devoid of stinging hairs. The leaf surface, unlike any other species known to us, is decidedly undulate, so that the plant can readily be recognized even before it blooms. The vine is fully as ornamental as the Florida velvet bean and should become a popular arbor plant, especially if the seeds are as edible as indicated by Roxburgh and others.

Prof. P. H. Rolfs, of the Florida Agricultural Experiment Station, and five other persons tested the edibility of the seeds prepared as baked beans. While they were found to be very palatable, they caused both purging and vomiting. Three of the persons who ate about half as much of the dish as they would of ordinary baked beans were thus affected. The other three who ate of them very sparingly suffered no ill effects.

The pods and seeds of this species are well represented in Plate IV, *A*. The flower clusters are longer than in any other species.

STIZOLOBIUM HASSJOO.

Stizolobium hassjoo n. sp. Yokohama bean. (Pl. V, *B*.)

Vines slender, 6 to 20 feet long, sparsely pubescent with retrorse white hairs; leaflets ovate, acutish, abruptly mucronate, rather thick and firm in texture, plane, 4 to 5 inches long, sparsely pubescent on each face with white appressed hairs; racemes 4 to 6 inches long; flowers dark purple; calyx saccate, the lower lobe one-half longer than the lateral ones, densely appressed-pubescent without and within; corolla 1½ inches long; pods 4 to 4½ inches long, 5 to 6 seeded, covered with rather long white appressed pubescence; median ridge prominent, the secondaries faint or wanting; seeds ash colored, often blackish at the ends, oblong, flattened, 15 to 18 mm. long, the veins of the testa very obscure.

This is S. P. I. No. 25254, obtained from the Yokohama Nursery Company, Yokohama, Japan, who state that this plant is widely grown in Hokkaido or Yezo, the north island of Japan. In the "Useful Plants of Japan," 1895, page 9, where it is erroneously identified with *Mucuna capitata* Wight and Arnott, the following information is given:

> Jap. *Osharaku-mame, Hassho-mame;* an annual leguminous climber cultivated in common dry land. The young soft grains are eaten boiled and have a taste of *Vicia faba* L., but this bean contains a poisonous ingredient in a slight quantity; so it is advisable to eat moderately.

Stizolobium hassjoo is by far the earliest species known to us. Planted at Biloxi, Miss., April 19, 1909, it was perfectly mature and dry on September 20; at Gainesville, Fla., it was fully mature by September 27, having been planted on May 1; at Monetta, S. C., it was planted June 15 and the pods were mature enough to ripen when the vines were killed by frost on October 25; at the Arlington Experimental Farm, near Washington, D. C., it was in full bloom on October 12, having been planted on June 21. The individual plant will cover a plat 3 to 4 feet square, which will indicate the proper distance to plant.

This species was also grown at Manhattan, Kans., in 1890 under the name *Mucuna capitata*, by Prof. C. C. Georgeson. From seed planted May 19 the plant began to bloom August 7 and matured a few pods before frost.[a]

This plant is mentioned by Siebold (Verhandelingen van het Bataviaasch Genootschap, 1830, vol. 12, p. 55) under the name *Dolichos hassjoo*, and the Japanese name "Hassjoomame" is cited, but no description given. We have thought it best, however, to use the same specific name.

STIZOLOBIUM ATERRIMUM.

Stizolobium aterrimum n. sp. Mauritius or Bengal bean. (Pl. IV, *B*, and Pl. VII.)

Vine very strong and vigorous, the stem striate but scarcely furrowed, covered with a soft, sparse pubescence; leaflets very large, plane, mostly acute, strongly mucronate, sparsely appressed-pubescent on each side; racemes pendent, 18 to 30 inches long, many flowered; flowers purple; calyx not saccate, densely appressed-pubescent without and within; pods falcate, about 4 inches long, black when mature, sparsely covered with a short, white, appressed pubescence; median ridge on valves prominent but sometimes broken; secondary ridge faint or wanting; seeds four or five, oblong, black, very shiny, 10 to 12 mm. long, the prominent hilum white.

This species is apparently much more widely cultivated than any other and has been obtained from the following sources:

S. P. I. Nos. 19181 and 21300, from Piracicaba, Brazil.
S. P. I. No. 22031, from Sydney, New South Wales, under the name "Black Mauritius bean."
S. P. I. No. 22032, from Kamerunga, Queensland, Australia, under the name "Black Mauritius bean."

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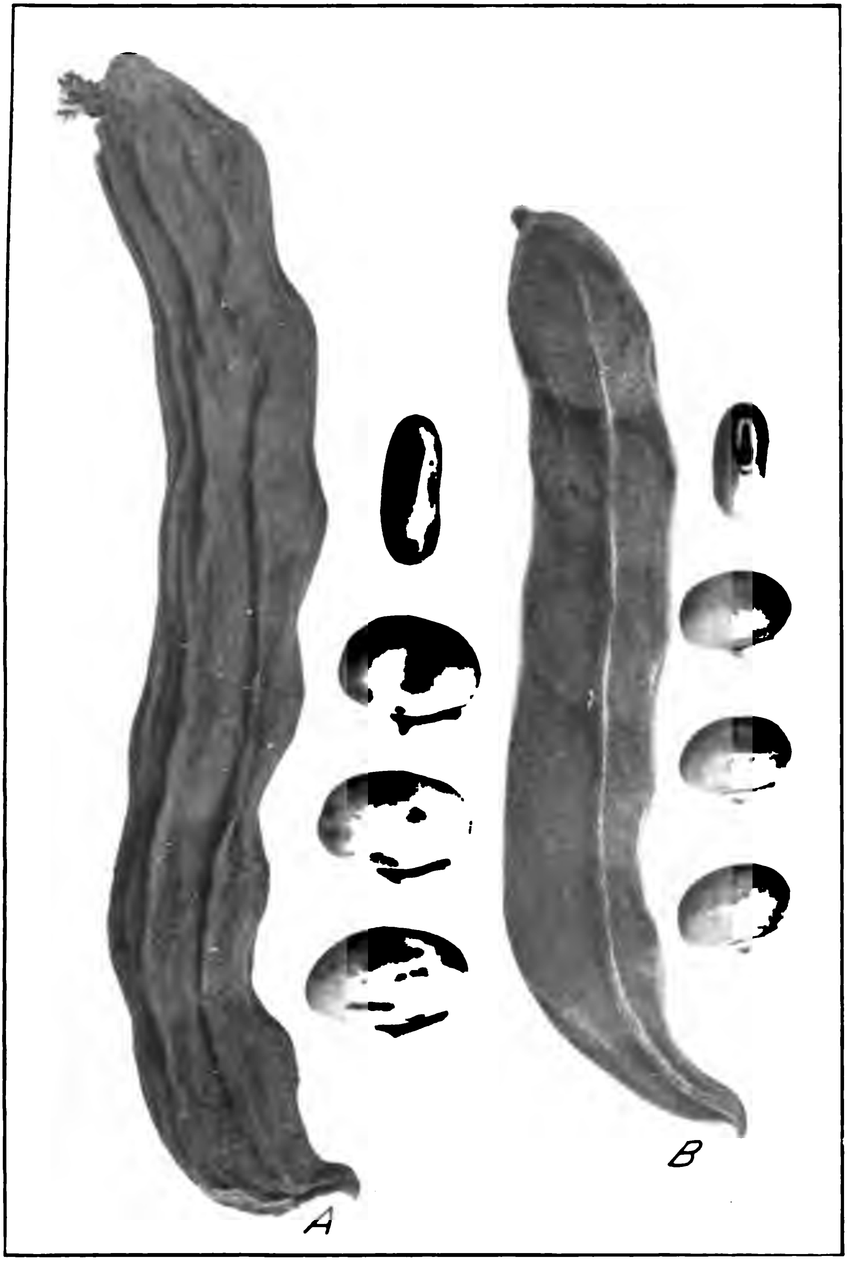
[a] See Kansas Agricultural Experiment Station, Bulletin 19, December, 1890, p. 199.

PLATE V.



MATURE PODS AND SEEDS OF STIZOLOBIUM PACHYLOBIUM AND STIZOLOBIUM HASSJOO.

A, Pod and seeds of Stizolobium pachylobium, S. P. I. No. 21094.
B, Pod and seeds of Stizolobium hassjoo, S. P. I. No. 25254.

(Natural size.)

S. P. I. No. 25262, from Saigon, Cochin China.
S. P. I. No. 24922, from Saigon, Cochin China.
S. P. I. No. 25870, from Barbados, under the name "Bengal bean."
S. P. I. No. 25755, from Mauritius.
S. P. I. No. 21951, from Buitenzorg, Java.
S. P. I. No. 21953, from Buitenzorg, Java.
S. P. I. No. 24935, from Colombo, Ceylon.

This species is also grown in Hawaii under the name of Mauritius bean, and has been obtained from Brazil under the name of Horse-Eye bean.

Both at Biloxi, Miss., and at Gainesville, Fla., this species grows to a much larger size than the Florida velvet bean, but is much later, so that the pods barely mature. On account of its extreme lateness it is not at all likely that it will be of value under American conditions. In Barbados Mr. John R. Bovell, the Superintendent of Agriculture, writes that it is grown to only a small extent for green manuring. He has never known it to be used for fodder or as human food.

In Mauritius, according to Director P. Boname, of the agricultural station at Reduit, the Florida velvet bean has proved to be much less luxuriant and valuable.

As already stated, this plant was identified by Voigt as the *Mucuna utilis* of Wallich. For the reasons given in the discussion under *Stizolobium utile*, we regard this identification as erroneous. There is still slight room for doubt in connection with this matter, which, however, can only be cleared up by comparison with the original type.

STIZOLOBIUM PACHYLOBIUM.

Stizolobium pachylobium n. sp. Fleshy-pod bean. (Pl. V, *A*, and Pl. VI.)

Vines stout, 40 to 60 feet long; stems sparsely pubescent with soft white hairs; leaflets 3 to 7 inches long, mostly acute, cuspidate, sparsely appressed-puberulent on both sides, especially on the veins beneath; racemes 1 to 2 feet long, the peduncle often bearing a small leaf; flowers dark purple, 1½ inches long; calyx appressed-puberulent without and within, the lower lobe little exceeding the laterals; pods large, 5 to 7 inches long, very fleshy when green, sparsely puberulent with weak white hairs, black and slightly falcate when mature, somewhat compressed, the valves mostly having two complete longitudinal ridges and several secondary ones; seeds much flattened, 18 to 22 mm. long, white with scattered black or gray spots.

The original seed of this, S. P. I. No. 21094, was presented to the Department by Mr. J. C. Vaughan, of Chicago.

It was sent to him by Mr. A. L. Kennan, from Talgarh, Midnapur, India, who writes: "The spotted bean is very productive, but is cultivated to a very limited extent by the Santals, one of the aboriginal tribes of India. They cook the green pods and also the ripened seeds, but do not like either very well."

This has larger seeds than any other species, and the pods also are the largest and least pubescent. It requires, unfortunately, a longer season than the Florida velvet bean by at least a month. Some of the clusters of pods of this bean measure 3 feet in length and bear over 50 pods.

The edibility of the pods and seeds has been tested by Mr. S. H. Gaitskill, of McIntosh, Fla., who writes:

> We have been giving the fleshy-pod velvet bean a trial. I could not get the negroes to try it until I had eaten it and had Mr. Dedman try it; then the negroes tried it. I do not consider it a fine-flavored bean, but has no bad taste; in fact, is quite palatable, and there were no bad effects at all. I would call it an edible bean.
>
> We found the bean better than the pod, and it might be that it would be more palatable to let them get fairly ripe and use them as shelled beans.

An important characteristic in which this species differs from the others is that the pods do not dehisce at maturity, but the pods can be broken in pieces without the valves separating. This character will very likely be valuable in crossing with the Lyon bean and others which dehisce rather too easily and thus shatter seed.

STIZOLOBIUM VELUTINUM.

Stizolobium velutinum (Hassk.) n. comb.

Mucuna velutina Hassk. (Beiblätter, p. 77, to Flora, 25th year, 1842, vol. 2.)

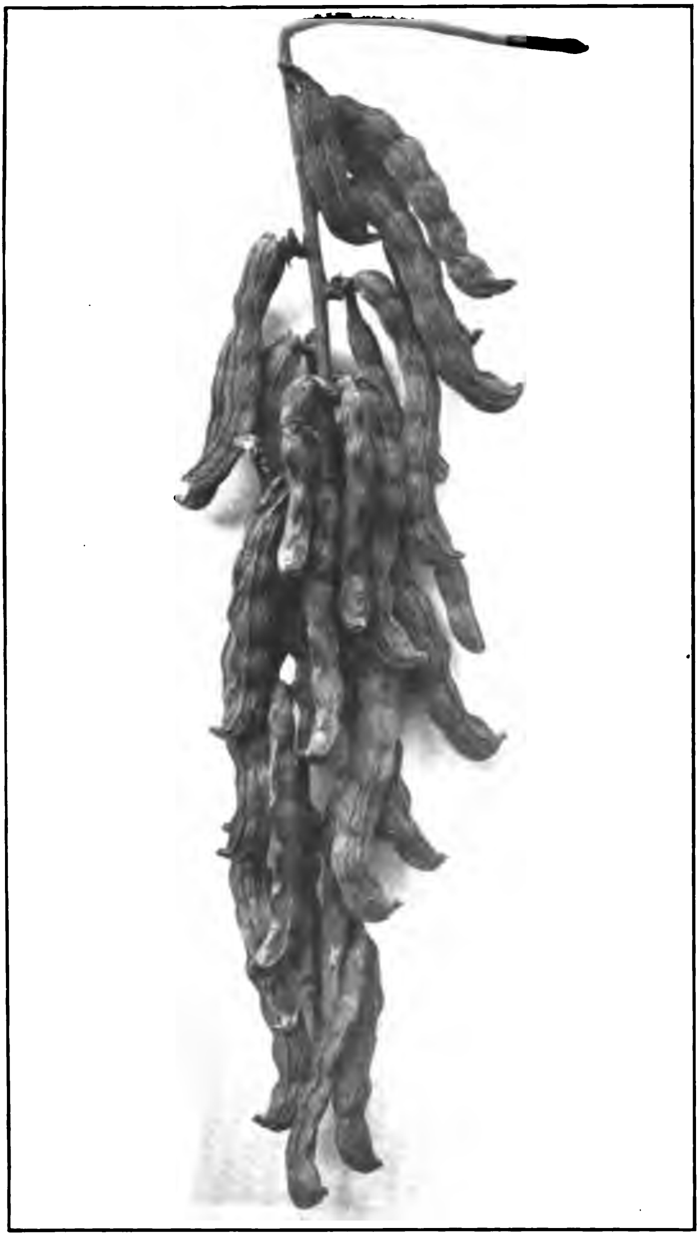
The original description is as follows:

> *Mucuna velutina.* Nom. sund. *Kwas boddas.*
>
> Legumina lamellis transversis fere distituta:—Racemis abreviatis 6—4, 5 poll. long. 0, 5 pll. crassis densissime velutinis subtereti-oblongis apice curvatis 6-loculatis, seminibus compressis;—foliolis (lateralibus oblique–) ovatis mucronulatis utrinque pilis adpressis minutissimus sparsis (in junioribus & calyce sericeis); corolla alba. Caulis volubilis, petioli pedales, stipellæ subulatæ,—Spec. intermedia M. mitem inter & mollem DC. Prdr. II. 405.

Hasskarl later published a modified description (Catalogus Plantarum in Horto Botanico Bogoriensi, 1844, p. 277), as follows:

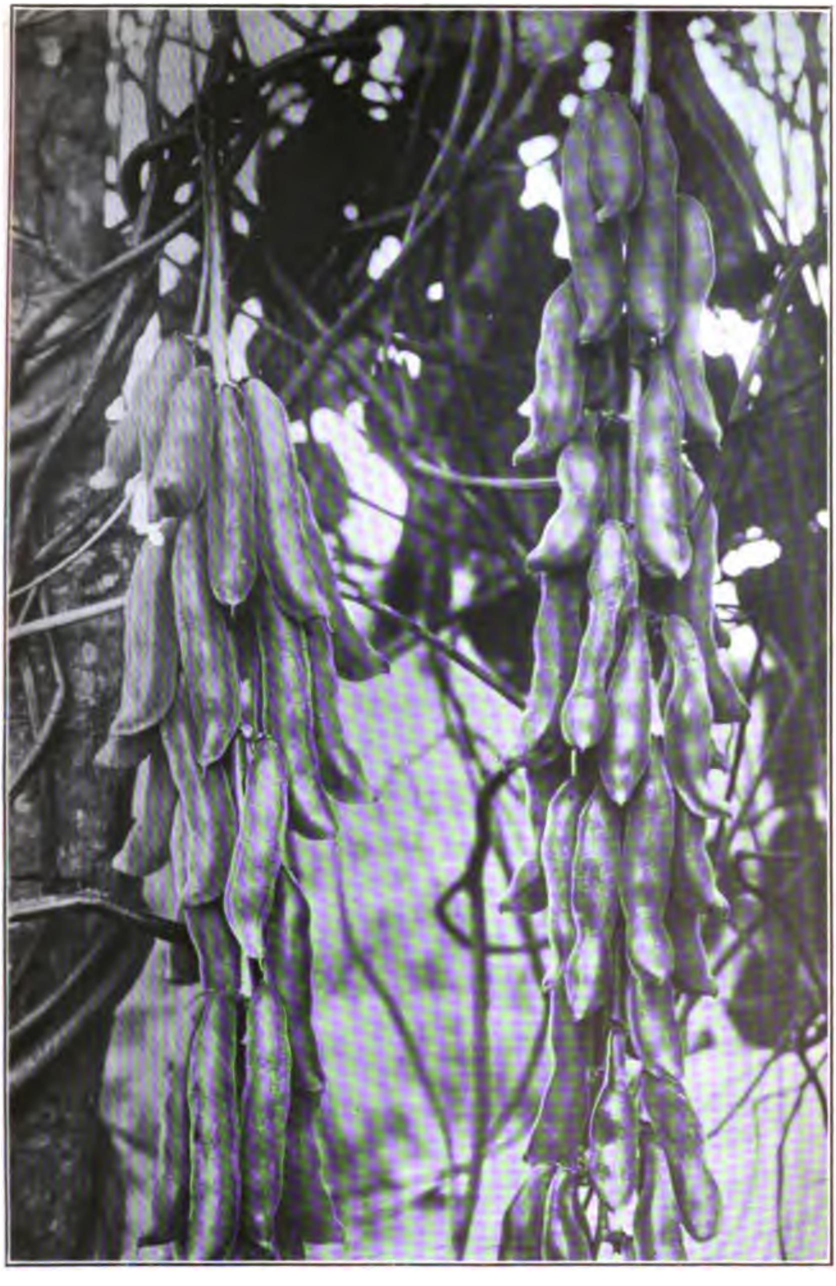
> Mucuna velutina. Kwas.
>
> Floribus racemosis, bracteis subnullis, leguminibus densissime velutinis subtereti-oblongis, apice curvatis vix 6– (sub 1–) loculatis, foliolis ovatis mucronulatis utrinque pilis minutissimis adpressis sparsis.—Variat seminbus nunc maculatis majoribus minoribusve (Kw. boeriek gedeh & leutiek) nunc immaculatis albis rugosis s. lævibus (Kw. boddas mengrœt & lietjien) aut viridiusculis aut nigris (Kw. heedjoh s. hiedung).

Through the kindness of Dr. M. Treub, director of the Buitenzorg Botanical Garden, we have obtained seeds of all the sorts now grown there. These include the following S. P. I. Nos.: 21951 and 21953, with black shiny seeds; 21952, with ash-colored seeds; 24657, marbled ash and brown; 24424, reddish to pinkish gray, more or less marbled with black or brown; 21955, greenish yellow or brownish, clouded



CLUSTER OF RIPE PODS OF FLESHY-POD BEAN (STIZOLOBIUM PACHYLOBIUM) GROWN AT MCINTOSH, FLA.

(Two-sevenths natural size.)



CLUSTERS OF GREEN PODS OF MAURITIUS BEAN (STIZOLOBIUM ATERRIMUM), S. P. I. No. 24922, GROWN AT GAINESVILLE, FLA.

(One-third natural size.)

over with black, perhaps the same as 24424, but with discolored seeds. There was also found in some asparagus bean seed from Buitenzorg a variety with greenish-yellow seeds, No. 0840.

Doctor Treub writes, under date of April 26, 1909:

> The three varieties described by Hasskarl, (1) "Kwas boeriek," (2) "Kwas hiedung," (3) "Kwas boddas," are now grown in our botanical garden under the following names: (1) *Mucuna velutina* Hassk. var., (2) *Mucuna capitata* var. *nigra*, (3) *Mucuna capitata* var. *alba*. The subvariety described by Hasskarl with rough seeds ("Kwas boddas mengroet") seems to be no more present.

It will be noticed, however, that there were received from Buitenzorg more kinds than Doctor Treub mentions. Of these S. P. I. Nos. 21955 and 0840 failed to germinate; Nos. 21951 and 21953, with black, shiny seeds, proved to be identical with the Mauritius bean; No. 21952, with ash-colored seeds, is a very late sort with purple flowers, but the pods did not mature; Nos. 24424 and 24657, both with marbled seeds, also did not mature at Biloxi, Miss., or Gainesville, Fla., but have been grown to maturity in the greenhouse.

Since Hasskarl in his first description referred only to "Kwas boddas," that is clearly the type of the species. It will be noted that in the first description Hasskarl states that this has white flowers. According to his second description, Kwas boddas has white seeds, rough in one form and smooth in the other, but the color of the flowers is not mentioned.

In a comparatively recent publication from the Buitenzorg Garden, Burck (Annales du Jardin Botanique de Buitenzorg, 1893, vol. 11, p. 187) considers *velutina* identical with *utilis* and reduces both it and *capitata* to varieties of *Mucuna pruriens*. According to him, var. *utilis* (*velutina*) has the seeds white, fuscous, or fuscous-maculate. He does not specify the color of the seed of var. *capitata*.

None of the kinds that we have secured from Buitenzorg and grown fulfills these conditions of white flowers and white seeds, as all that grew had purple flowers and only one had seeds that can be called white. There remains S. P. I. No. 0840, with greenish-yellow seeds. This seems to be identical with S. P. I. No. 25756, received from Mauritius, and that does have white flowers. This, however, would seem to fit best with Hasskarl's "Kwas heedjoh," the seeds of which are described as greenish, "viridiusculis."

We are therefore at a loss to determine the identity of the real *Mucuna velutina*, which seemingly is not contained among those grown by us, unless it may indeed be identical with *Stizolobium niveum*, the only species we as yet know with white flowers and white seeds.

As before stated, the species with black, shiny seeds proves to be the same as the Mauritius bean. The two kinds with mottled seeds are probably distinct species.

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B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURAL AND BOTANICAL EXPLORATIONS IN PALESTINE.

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AGRICULTURAL AND BOTANICAL EXPLORATIONS IN PALESTINE.

INTRODUCTION.

The economic and agricultural importance of the Orient is beginning to be appreciated in the United States more than anywhere else. Agricultural explorers have not only brought back important economic and ornamental plants, but have gained broader views and have seen the possibilities for a wonderful new development in agriculture. They have learned in the Orient that there is every reason to hope that the vast arid and semiarid regions of America can be rendered productive, although from the point of view of the European agronomist they would appear as worthless deserts.

Economic exploration rather than scholarly research is needed to make the countries of the Orient known and appreciated abroad and to renew a belief in the ancient saying "ex Oriente lux" (light comes from the Orient). The United States may expect its most valuable agricultural introductions from the Orient. The Smyrna fig and the Thompson Seedless grape have already been brought from the Orient, to mention only two examples of fruits. From the Orient have also come the oats of Kherson and the hard wheats of Russia and Turkey, which have made it possible to extend the cultivation of cereals to regions that were uncultivated before their introduction. But this is only the beginning. My own observations in the Orient, as well as in the Middle West and Southwest regions of the United States, lead me to believe that all that has been done in this direction is only a splendid beginning.

In fact, the Orient still remains almost unexplored and unknown as to its agricultural possibilities. In the oriental countries can be found almost all of the wild types which our prehistoric ancestors utilized in producing the cultivated crops of our time. Here, also, are to be found some of the best cultivated varieties, developed by the combined efforts of man and nature for thousands of years. New countries, especially those of the west, can here obtain the plants best adapted to their needs.

An idea of what the Orient holds for those who will take the trouble to explore it can easily be gained by considering the useful plants which I think should be introduced from Palestine, a part of the Orient which I have made my special study.

ANALOGY BETWEEN PALESTINE AND CALIFORNIA.

Palestine is more like the State of California than any other in the Union in everything except size. It lies between longitude 34° 30′ and 36° 30′ east, and between latitude 30° 30′ and 33° 45′ north. It is practically a California reduced to about one-twentieth in size but markedly similar in general topography, climate, vegetation, and agricultural and economic possibilities.

GENERAL CONFORMATION OF PALESTINE.

Like California, Palestine (see fig. 1) is longest from north to south. Like California, too, it has both very high mountains, having an elevation of 9,000 to 10,000 feet, and very deep depressions. The Dead Sea, 1,200 feet below sea level, is the greatest depression known, and, like the Death Valley of California, it is situated in the southern extremity of the country.

Such formations always give rise to a great diversity of soil and vegetation. Where a very ancient civilization exists, as in Palestine, such formations likewise favor the development of many varieties of cultivated plants and give rise to different methods of cultivation.

Passing from west to east, we have in Palestine (see fig. 2) the coast zone, extending along the Mediterranean, similar to the littoral region of the Pacific, and the zone of hills and plateaus of the mountains of Judea and Galilee, forming, so to speak, the backbone of the country and being similar to the foothill region of California. Farther east we have the valley of the Jordan, the diversified parts of which are similar in soil, climate, and agricultural possibilities to the San Joaquin, Imperial, and Death valleys. Finally, still farther east are the plateaus of the Trans-Jordan, with their fertile soils of volcanic origin, devoted from time immemorial to pastures and the cultivation of cereals. They are regarded as the granary of the country and have been famed since Bible times for the abundant herds of Bashan. Extending eastward these plateaus pass into the steppes and, finally, toward the south, form the deserts of Syria and Egypt.

CLIMATE AND RAINFALL OF PALESTINE.

In Palestine, just as in California, we have a dry, warm season and a humid and more temperate one. The rainy season extends from October to May, and the dry season from May to October. The rainfall varies, according to the locality, from less than 6 inches in the extreme south near the Egyptian frontier, where rains are insufficient and uncertain, to more than 40 inches in the north of the country.

Palestine is even more favored than California with regard to the winter temperature. Although the thermometer rises as high in summer in Palestine as in California, with extremes of 110° to 115° F., though not so often, it very rarely drops in the winter to the freezing point. Snow is rare, even on the plateaus, and our farmers are practically safe from any damage by frost over nearly the entire extent of the country.

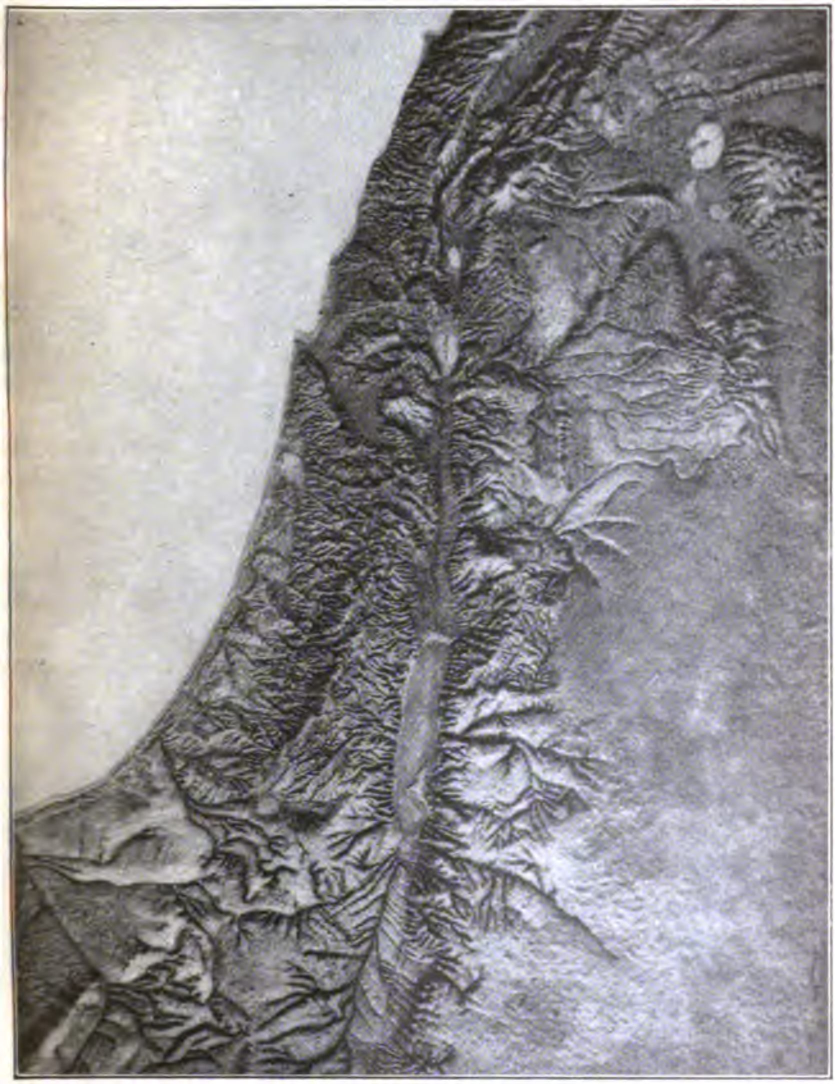


FIG. 1.—Relief map of Palestine, showing the coast region, the Jordan Valley, and the unexplored regions of the east.

GEOLOGICAL FORMATIONS OF PALESTINE.

Geologically the Paleozoic age in Palestine is represented in t extreme southeast by granite and gneiss; the Secondary formatio

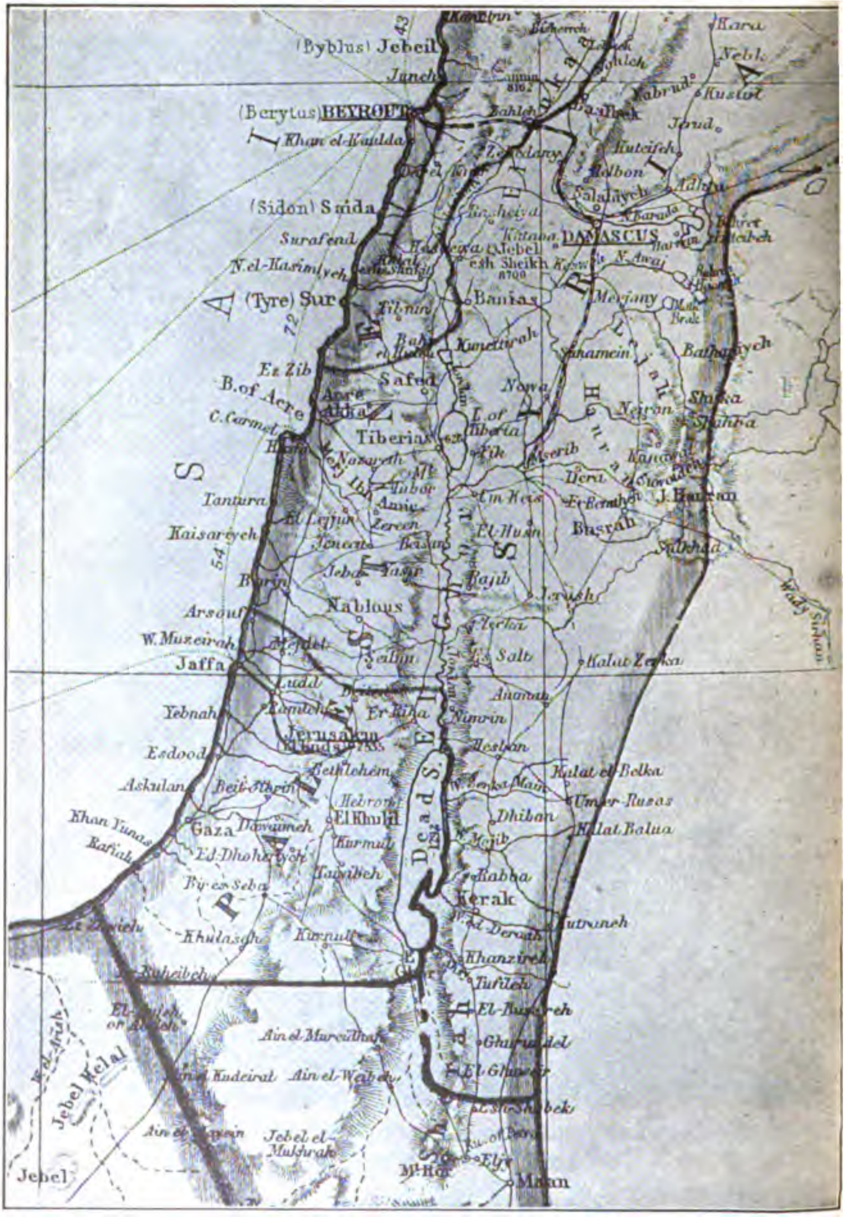


FIG. 2.—Map of Palestine, showing the location of the principal towns and villages.

appear in the extreme northeast in the Jurassic, and the Cretaceous is found everywhere in the form of sandstone, hard limestone, and dolomite belonging to the Cenomanian and Turonian ages and soft limestones and beds of flint being generally attributed to the Senonian age. Finally, my own discoveries have shown that the lower Eocene of the Tertiary age, which was unrecognized for a long time, covers a vast area here. This formation is abundant in the south, where erosion has reduced it to thin layers, and in the north, where it is characterized by nummulitic limestone. Finally, there are the Pliocene and the Pleistocene, the alluvial, diluvial (see Pl. I, fig. 1), and volcanic deposits, which in the form of basalt and basaltite are found over vast stretches of territory in Samaria and lower and upper Galilee, and especially in the Trans-Jordan. The Trans-Jordan is very similar to the vast volcanic region of California and Oregon, and to that of Idaho in the neighborhood of Pocatello and in other localities in that State.

Because of its diversified geologic formations the country presents a great variety of soils, but fortunately the calcareous element predominates, for it is this element which is of the greatest importance in the soils of arid and semiarid regions, being second in importance to water only, which is indispensable for maintaining animal and vegetable life.

As is to be expected from this great variety of soil and climate, the vegetation of Palestine is remarkably rich in species and presents types of both desert and alpine floras.

VEGETATION OF PALESTINE.

Curiously enough, the list of the flora of the small territory of Palestine includes approximately the same number of species as that of California—about 3,000. This is nearly twice as many as are known in Algeria, which has the same variations of soil and climate as Palestine but is about fifteen times as large.

There are many other points of similarity between the vegetation of California and that of Palestine. In both sections evergreen shrubs predominate. The same forms of vegetation, often the same genera, are found on Mount Tamalpais, California, and on Mount Carmel, Palestine; the maqui formation of Palestine is to be compared to the chaparral and chamiso of California, and the forms of vegetation of the Lebanon and the Hermon mountains are much the same as those of the western slope of the Sierras.

On account of the predominance of the calcareous element in the Palestine soils already mentioned, the lime-loving leguminous plants are well represented. The genera Medicago, Melilotus, Trigonella, Astragalus, Trifolium, etc., are rich in species which aid in maintaining fertility by means of their nitrogen-fixing character. These furnish good temporary pastures in winter and spring, and during the long, dry summers the cattle relish the hulls which cover t ground. The introduction of these remarkable leguminous plan into the Southwest, and their cultivation and selection, may be e pected to contribute greatly to the improvement of the range. Th analogy of the flora of Palestine with that of California justifies o expectation of the best results. The plants of Palestine are, so speak, the homologues of those of California, and, a priori, the success seems assured.

The success of the useful xerophytes (see fig. 3) and halophyt of the Palestine deserts when introduced into the Southwest oug to be even more certain than would that of the plants of the Sout west if transferred to Palestine, and for the reason that in the dese districts surrounding Palestine the rains come, when they come all, only during a single short season between October and Marc On the contrary, in Arizona, for example, there are two rai seasons during the year. This would be a great advantage to t leguminous annuals and grasses introduced from Palestine.

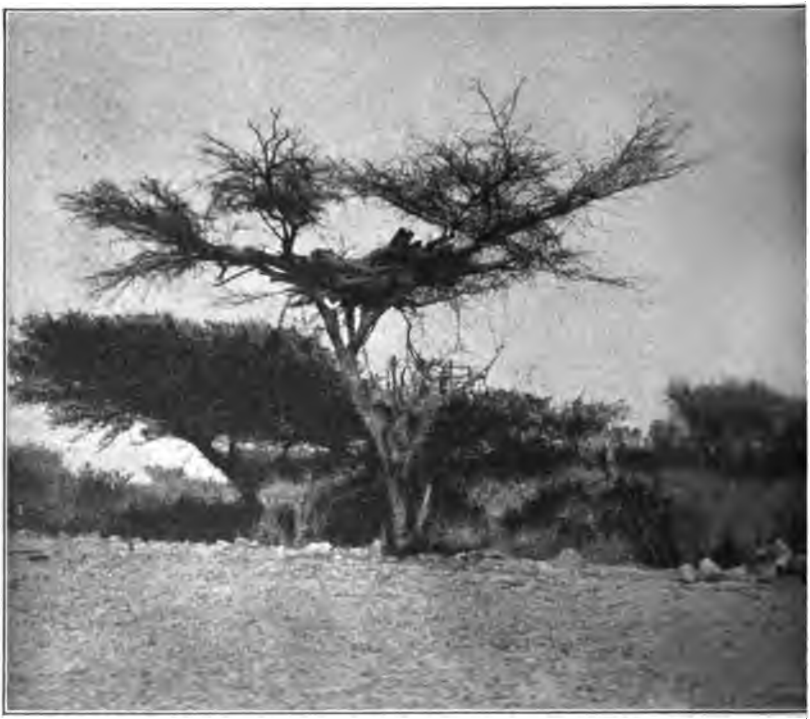
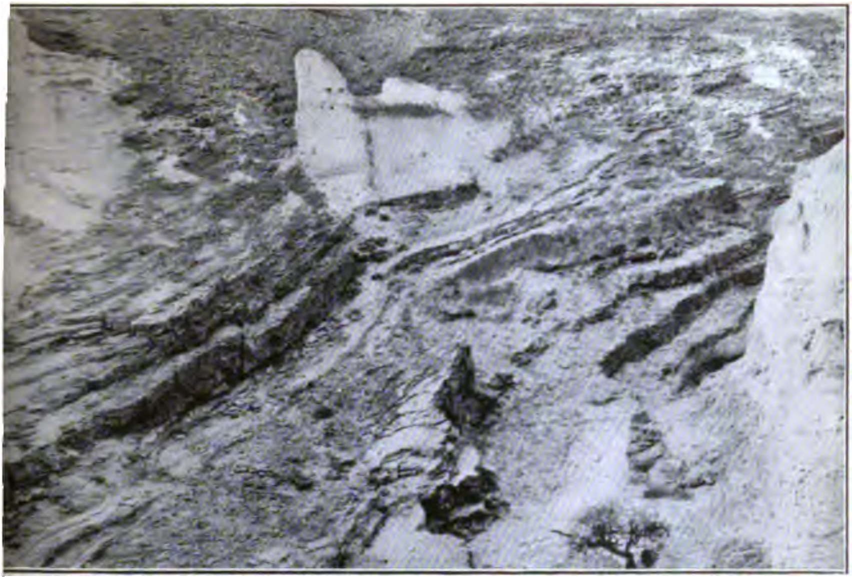


FIG. 3.—Seyal acacia tree near Engedi, on the western shore of the Dead Sea. The rou flooring in the branches is used by Arabs as a summer dwelling.

In the territory with which we are dealing we have, as has be shown, a large number of wild species and varieties. If we co sider the varied natural conditions of Palestine and the pecul



IG. 1.—KASR-EZZUWEIRA, SHOWING THE EFFECTS OF EROSION ON THE "LISSAN" STRATA, LAYING BARE THE UNDERLYING ROCKS.

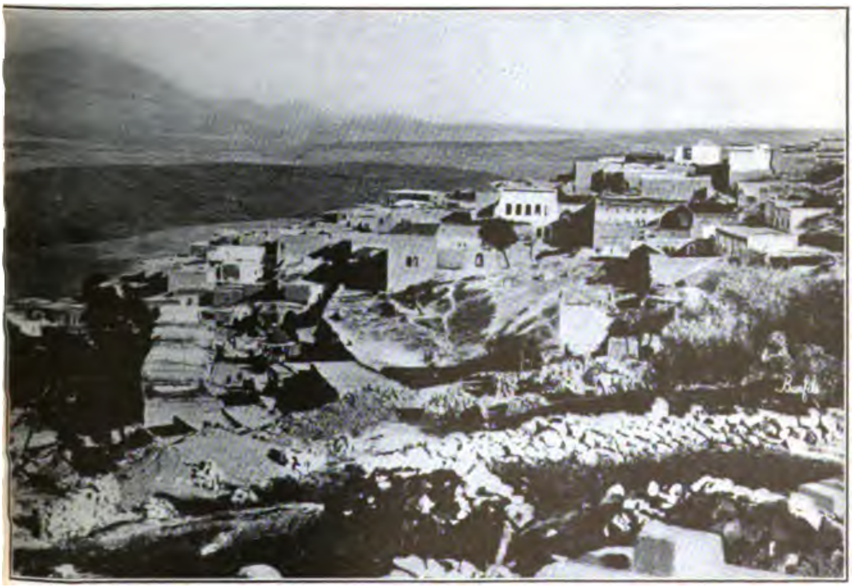


FIG. 2.—VIEW OF SAFED. ON THE LEFT IS THE ROCKY MOUNTAIN, DESTITUTE OF FOREST VEGETATION, WHERE TRITICUM DICOCCUM DICOCCOIDES WAS FOUND.

methods of cultivation which have been brought about by political conditions—the vicissitudes of war, the continual migration of tribes, and colonization—all acting through such long periods of time, we can readily understand why so many varieties of cultivated plants have been developed and why the country is such an interesting one to study and is so full of promise.

ECONOMIC PLANTS WORTHY OF INTRODUCTION INTO THE UNITED STATES.

PLANTS RECOMMENDED AS STOCKS.

Zizyphus spina-christi (*Christ-thorn*).—This tree averages 16 feet or more in height, with a diameter of 16 to 24 inches. Its fruit, about the size of a hazelnut, is not so well liked as that of the species mentioned later. It is a tree which is found along the coast and in the valley of the Jordan. There are several local races adapted to different life conditions. In the valley of the Jordan, and especially farther south in the valley of the Arabah, it is the most common tree on alkaline soils.

The Arabs water their land very abundantly and do not provide any drainage, and as a consequence great quantities of alkaline salts are brought to the surface. At the end of two or three years the soil is so excessively salty that the land is abandoned for a number of years until the rains have washed the salt down into the subsoil. *Zizyphus spina-christi* grows on these lands abandoned on account of their excessive alkalinity, so that when an explorer finds a field overgrown with this plant he can be sure that it has formerly been under cultivation.

Zizyphus spina-christi inermis.—In very moist lands along the banks of streams, for example those of the Jordan near Jericho, the type plant loses its thorns (thorny stipules or stipular spines). The resulting variety is called *inermis* (spineless).

Zizyphus lotus.—This bush rarely grows to a height of 6 feet. It tends rather to give off suckers, thus spreading continually and forming clumps of large diameter. This characteristic makes the plant very valuable for the fixation of dunes. It seems to be more particularly adapted to inland dunes, although it has been grown successfully along the coast. The fruit of this species, although smaller than that of *Z. spina-christi*, is more palatable and, under the name of "Dôm," is eaten dry by the Arabs throughout the valley of the Jordan, and also by the Jews of Tiberias. The taste is a little like that of dried apples.

Zizyphus lotus seems to be less adapted to alkaline ground than *Z. spina-christi*, but grows on the most arid hills. In the vicinity of Tiberias and farther south and east it is the only bush which grows on the black basalts, where in summer a burning temperatur prevails.

I believe that *Zizyphus spina-christi* and *Z. lotus* may be of grea value as stocks for Chinese jujubes or t'saos (*Z. sativa*) and that b their use we can extend the cultivation of this fruit to regions wher it is now absolutely impossible on account of excessive dryness o excessive alkalinity of the soil. These stocks seem to me to be espe cially adapted to the Imperial Valley of California.

Paliurus spina-christi.—Another species related to the two alread mentioned is *Paliurus spina-christi.* This is a bush 10 to 13 fee high. It does not extend so far south as the two preceding species but thrives on the plateaus of upper Galilee, where it is used fo hedges around unirrigated olive plantations, and also at the foot o Mount Hermon, where hedges of it are planted around irrigate fields.

This species, also, should be tried as a stock for the Chinese jujube It is adapted to less arid soils than *Zizyphus lotus* and does well on those having a considerable degree of moisture and in regions wher the winters are relatively severe.

If these three species, *Zizyphus spina-christi*, *Z. lotus*, and *Paliurus spina-christi*, graft readily with the Chinese jujube, we shall have stocks for this fruit available for all kinds of soil—moist, arid, and alkaline—and for both high and low altitudes—from 3,300 to 4,000 feet above to 1,300 feet below sea level.

Pistacia terebinthus and Pistacia palaestina.—These species will furnish stocks for *Pistacia vera*, the true pistache nut, a crop which can be made of great value in the United States but which has not as yet been much cultivated here. Each of these species is 13 to 26 feet high and 2½ feet or more in diameter. They are found in all sorts of soil, particularly in crevices of calcareous rocks. *P. palaestina* is found more frequently than *P. terebinthus*, which seems to prefer moister soils. The former grows in the valley of the Jordan and extends as far as Petra and the Arabah, generally in slightly moist sandstone soils. This plant is especially to be recommended for the vicinity of Indio and Mecca, Cal.

Pistacia atlantica.—This variety has proved to be a good stock for *Pistacia vera* (the pistache), and I believe that *P. terebinthus* and *P. palaestina* will also prove valuable and should be imported and tried in the United States. The male flowers of *P. terebinthus* are often used in Asia Minor for the pollination of *P. vera*, and it may be that in this way we can increase the productiveness of *P. vera* in the United States, where hitherto it has not yielded well.

Amygdalus communis.—The wild almond is very common in Palestine and Syria; that is, a really wild almond, not one that has escaped from cultivation. It covers a very extensive area, and therefore a number of varieties and local races have developed. These merit careful study. Some are found in the cretaceous and nummulitic rocks of Samaria; others prefer the basaltic hills of Gaulanitis, etc. These wild almonds are plentiful enough to furnish an article of commerce. The Bedouin women of Gaulanitis (Djôlan) gather the bitter almonds and carry them to the market at Damascus. We get wild almonds from the region of Nablus (the ancient Shechem) from which to grow stocks for our nurseries. They are excellent stocks for almonds and for apricots on dry and nonirrigable lands.

Amygdalus orientalis.—I believe that this species is also worthy of being recommended, although I must admit that I have had no personal experience with it. It is common on Mount Hermon, and I know it to be one of our hardiest species. It thrives in crevices of rocks looking toward the east, thus being exposed to the hot, dry winds of the desert. It extends to altitudes of 3,300 to 5,000 feet and is very resistant to the rigorous winters of these high regions. It is therefore one of the best species to test as a stock for poor soil in barren regions. It should prove valuable in Washington, Oregon, and Colorado.

Prunus microcarpa and Prunus ursina.—All that has been said about *Amygdalus orientalis* applies also to *P. microcarpa* and *P. ursina*, which appear in the same localities and under the same conditions. The fruits of *Prunus microcarpa* are slightly bitter but very refreshing, and the writer has often enjoyed them when tired out from long walks in this region. The seed has a thin shell which is easily broken.

Prunus ursina (bear plum) has a globular fruit, violet-red or yellow when ripe, an inch in diameter. It takes its name from the fact that bears, said to be formerly numerous on Mount Hermon, but now exceedingly scarce, are very fond of it. It is also eaten by the shepherds and by the wives of the peasants. It is a bush 6 to 10 feet in height, with a trunk 4 inches to 1 foot in diameter.

Prunus cerasia.—This shrub is very interesting on account of its fruit, which is quite similar to the damson in taste and appearance. The seed, however, is longer and more pointed. The fruit is oval and one-half inch to 1 inch in length. This shrub is cultivated more for stock than for its fruit, which is astringent and not very agreeable. It is possibly the prototype of the cultivated damson. This seems the more probable from the fact that the word "damson" is thought to have been derived from Damascus.

Crataegus.—Among other species of Crataegus the most important is *Crataegus azarolus* with its numerous varieties and races. This is a shrub of the calcareous hills and appears only on very dry lands. If undisturbed it grows as high as 13 to 16 feet, but its branches are generally hacked off for fuel by Arab women or mutilated by heavy stones thrown by the boys to shake down th fruit. Some varieties of *azarolus* have fruit as large as a larg cherry, with a very agreeable acid taste. Although they are sold o the markets of the Orient, they would not be marketable in Europ or America because of the large stones, as in the case of the loqu (*Eriobotrya japonica*); but specimens are often found which a nearly stoneless, and it is possible that this character could be fixed b selection.

For fifteen years or more the writer has used *Crataegus azarolu* as a stock for pears with excellent results. Top-grafted at 2 to feet above the ground, it develops into very beautiful, productiv and long-lived dwarf trees, provided the grafting is done with ver early varieties. This shrub occurs in extremely hot, dry places an must therefore complete the greater part of its development earl in the season. Its roots, therefore, are unable to furnish the amoun of sap necessary to develop pears in August. If, however, it i grafted with a pear which fruits in May or June, when the roots o the Crataegus are in their period of greatest activity, the best result are obtained. I have found this to be true in Palestine, and M Dumont, near Tunis, who has grafted hundreds of wild Crataegu plants, also finds that he is successful only with early varieties o pears.

I may also mention *Crataegus orientalis*, having a large an palatable fruit, and *Crataegus sinaica*. Although the fruit o this species is scarcely larger than a pea, with a dry and tasteles flesh, it will grow on the very driest lands. All of these species o Crataegus are spiny. They are par excellence the stocks for pears o dry lands and calcareous ridges. The writer speaks only of pears because he has experimented with them, but he sees no reason a prio why these stocks should not do as well for apples, which he has no as yet tried.

Pyrus syriaca.—This wild pear ought to be considered alon with the species of Crataegus. It would be adapted to an eve greater range of soil, for, though the Crataegus species appear onl on very porous soils, some races of these wild pears grow in ver humid localities, almost swampy, or at least submerged for two o three months of the year. *Pyrus syriaca* is a shrub 13 to 20 fee high. The branches of young plants and the suckers at the base o the trunks of old trees are very spiny, but there are no thorns at th top. The fruit is a favorite with the peasants and shepherds. I grows, as said, on damp soils at sea level; it is also found in th forests and underbrush on hills and plateaus. Sometimes a singl tree stands by itself without any protection from the winds and th burning sun. It grows at 2,500 to 3,000 feet altitude on the Senonia chalks, as well as on the dolomitic and nummulitic limestones o upper Galilee and also at 3,300 feet and more on the Jurassic beds and the lower Cenomanian sandstones of the slopes of Mount Hermon. It seems to the writer to be a very promising stock. It was in this region that Kotschy found some wild pears, which were so good in flavor that he named them *Pyrus nobilis*.

FRUITS.

In addition to the wild types which are excellent for stock and may yield some valuable results by hybridization and selection, we may note some of our cultivated fruit varieties which would be worth trying in the United States.

APRICOTS.

The almond is generally used as stock for the apricot, except in irrigated orchards such as those in the region of Damascus, where the varieties desired are grafted on "Muschmusch kelabi" (dog apricot, or bitter-seeded apricot). *Prunus spinosa* is rarely used as stock, and then only in northern Syria.

Syria and Palestine have a great number of varieties of the apricot. I have secured from Damascus alone eight varieties for my own use. There is a difference of fully two months between the ripening of the earliest and of the latest varieties in this one place under the same conditions of cultivation. These varieties differ in habit of growth, productivity, appearance, and taste of fruit. Only one variety, "Muschmusch kelabi," has bitter kernels; the kernels of all of the others are sweet and are eaten like almonds. The annual export of "kelabi" kernels from Damascus alone averages 60,000 pounds. Some varieties have especially good shipping qualities. They are packed, without being wrapped, in boxes that have been used for the importation of Russian petroleum. They are carried upon mules, sometimes for two or three days, over precipitous, rocky paths, and yet, in spite of all this and of their being exposed to great variations of temperature, they reach the markets in excellent condition.

Other apricots, like the "Tadmuri" (meaning Palmyrian), though splendid fruits, are not very productive and would not stand the conditions just described.

The "kelabi" is used only for the manufacture of apricot paste. Spread in a thin layer and dried in the sun, it looks like a piece of leather. It is treated with a little oil, so as to prevent its becoming brittle. It can then be rolled up, and, being very easy to carry, it forms an important part of the rations of the Mohammedan soldier. On account of its value to him in his religious campaigns it is called "Kamr-ed-din" (the crescent). This paste is an important article of commerce, and I shall later write a special article on its preparation and uses. Here I wish only to say that, at my suggestion, some experiments in its manufacture were made during the present year in the Santa Clara Valley, California, and with a gratifying degree of success. It is therefore not impossible that the utilization of “slab” apricots in making this paste may prove of importance, especially during years when there is a large percentage of low-grade fruit. This may result in the establishment of a new industry for the utilization of apricots, the product being shipped to the mining districts.

QUINCES.

The quince is cultivated in different regions and under variou conditions of soil and climate. We have some varieties adapted t irrigated orchards only; others that yield fruit on the cool, but dry plateaus of Samaria. Some varieties have fruit edible when ripe others are always astringent. All yield a beautiful ruby-colore jelly of a very fine flavor.

POMEGRANATES.

Pomegranates are extensively cultivated in Syria and Palestin although the crop is not one of great commercial importance. The grow in wild thickets, having escaped from cultivation, and are ver drought resistant. Pomegranates are also cultivated in almost a orchards, both with and without irrigation. They comprise tw groups, the acid fruited and the sweet fruited. The latter includ those fruits with large, hard seeds and the form called “Malissi,” seedless. As a matter of fact they have seeds, but these are small an thin shelled. There are a great number of races among the “Malissi The “Bint-el-Bascha” (daughter of the pascha) grows at Gaza, i southern Palestine, at sea level. This name is given by the Arabs different fruits or products of special excellence. These varieties a found on deep, Quaternary soil and they require irrigation. Th have been famous from ancient times and are exported to Egypt a other lands. Er-Reineh, a christian village in lower Galilee, b tween Nazareth and Tiberias, is also known as Um-er-Rum (mother of the pomegranate), because so many varieties of su excellent quality are produced there. They grow at 1,000 to 1,3 feet altitude in calcareous soils. The pomegranates of Jericho a the oases are much liked. They grow readily in very alkaline soi

OLIVES.

We now come to two characteristically oriental crops, grown th for centuries and always of great importance, viz, the olive a the fig.

In spite of all that has been said and written about the Oleastrum, the Zeboudj of the Kabyles (Algeria), the writer believes that it is only an olive escaped from cultivation. The wild olive certainly originated in the hills and mountains of Syria and Palestine, rather than in those of Algeria. At any rate, there are different varieties or races of wild or half-wild olives in our hills adapted to all kinds of soil and to widely different climatic conditions. Though they would not be ranked botanically as varieties, there are three distinct races among our wild olives which are used either for direct planting or in our nurseries.

The first is a form with thin, brittle, blackish bark. This form is not much liked; it is difficult to propagate, grows slowly, is hard to graft, and the fruit produced by these grafts is said to be not very rich in oil.

Second, there is a form with waxy green bark. This is easily propagated, grafts readily, is very much liked, and when used as a stock gives a very large yield of oil, but it is of rather slow growth and it fruits late.

The third form has a thick, white or gray bark, which separates readily. It is particularly well adapted for grafting, is easily propagated, grows rapidly, and fruits early. It is said that the trees of this race do not live as long as those of the preceding one.

All of this information is not guaranteed, as some of it was obtained from the Arabs, but that part which relates to propagation, growth, and grafting is from personal observation.

There is, as is to be expected, a great multiplicity of forms in the cultivated varieties of olives (see fig. 4). In southern Palestine we have olives which grow under much the same conditions as the Chemlali of Sfax (Tunis), the soil and climate being about the same and the rainfall as limited. I may note, however, that the varieties from Gaza, Ramleh, or Lydda, which grow in southern Palestine on Quaternary soil, do not contain the excess of margaric acid which is characteristic of those from Sfax. This is a great defect in those varieties and is the cause of their oil being rated as inferior. To be sure, the oil of southern Palestine is also rancid and mediocre in quality when prepared in the Arab fashion, but excellent when well prepared.

Just as the name "Chemlali" is applied in Algeria and Tunis to several different forms, so also in Palestine the name "Nabali" has a somewhat indefinite use. The Nabali of Et-Tireh, near Haifa, growing on calcareous Cenomono-Turonian formation, and the Nabali of southern Palestine, growing on Quaternary soil, are altogether different. The first is richer in oil and is of superior quality. One form in this locality is particularly in demand because it is more productive and yields more oil, and that also of a finer quality. But we are not sure that this difference is really one of variety; the superiority i probably due to the soil. The villages of Et-Tireh, Ijzim, and Ai Ghazal (mother of gazelles), in the foothills of Mount Carmel, ar renowned for this superior olive. All the trees reported from ther were found to grow in rich land made up of volcanic tufa and disintegrated basalts from the old eruptions of the Secondary epoch.

Er-Rameh, in upper Galilee, 1,300 to 2,000 feet in altitude, hold the record for the productivity and quality of its olives. There i here a fair degree of uniformity in the character of the fruit, an the best methods of cultivation in the country are here in use.

A number of other varieties are found in the region of Damascus The altitude here is 2,000 to 2,300 feet, and the winters are rathe severe. Some of these varieties are especially rich in oil; others particularly well adapted for table use. The only one called "Damascus" olive remains green in color until ripe and is preserved simply by means of lye made of ashes. It is often as large as a pigeon's egg, larger than any of the Spanish "aceitunas Sevillanas" or "aceitunas de la Reina" that I have ever seen.

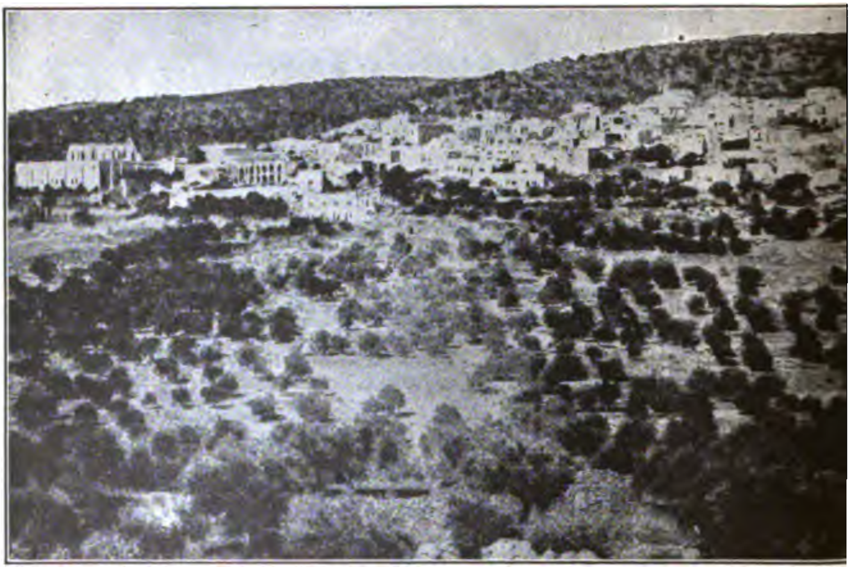


FIG. 4.—Olive groves on rocky soil in the environs of Jerusalem, showing artificial terracing

As the winters are mild in the particular regions where I have carried on my work, I have studied the resistance of our forms and varieties in relation to heat and drought rather than to cold. But as there are varieties growing in parts of Palestine where the winters are severe I have no reason to doubt that there are forms among these which will grow well in those parts of California, Texas, etc., where winter temperatures are relatively low. In fact, our olives extend through a vertical range of nearly 6,500 feet. They grow under irrigation at Abedieh and Jericho, in the valley of the Jordan, at 650 to 850 feet below sea level. They are commonly cultivated at Hermon and at Lebanon, 4,000 to 5,000 feet in altitude, where the winters are long and relatively severe. In upper Galilee—in the region of Safed, for instance—at an altitude of 2,000 to 2,500 feet, it is claimed that low winter temperatures increase the olive crop; for it is stated that whenever the winters are cold (that is, the temperature reaches 14° to 18° F.) the crop is always abundant. If this generally accepted opinion is true the increased production is to be attributed, according to my opinion, not to any beneficial effects of cold upon the tree but to the fact that such low temperatures probably kill most of the parasites, particularly the olive scale (*Lecanium oleae*). This is very prevalent and the people know no way of combating it.

FIGS.

Though the fig is not cultivated to so great an extent in Palestine as in Smyrna, it is, nevertheless, a very important crop, particularly in upper Galilee, where the population is very dense and labor is cheap. There are a great number of varieties there—some with black fruit, others with green, and still others with pink. Some of these figs can be used only while fresh. These are not very extensively cultivated, there being practically no shipping facilities. Other varieties are dried and pressed and, to some extent, shipped abroad. They are, however, chiefly consumed by the Bedouins, whose liking for "kutteins" (dried figs) is proverbial. These people are not at all critical, so that no effort has been made to improve the methods of preparing this product or to study the best varieties for cultivation.

It is our wild figs, however, rather than our cultivated varieties, that will probably prove of the greatest value in the United States.

Ficus carica.—This species and its numerous varieties grow wild abundantly in the crevices of rocks. The openings of the numerous mountain caves are generally shaded by these wild trees. In the valley of the Jordan, in the neighborhood of Fusail, there are patches of humid soil, of a black color generally, characteristic of the injurious carbonates. The wild figs nevertheless grow there, showing that they are particularly resistant to alkali. This fact should make them a valuable stock in California. The Smyrna fig has been established in California, but this variety does not show a great degree of resistance to alkali. I firmly believe that the local races growing in Palestine on alkaline soils will be of great value as stocks to the fig growers of California. I say "races" rather than "varieties" because the use of this latter word has been so much abused by some authors.

Ficus pseudo-sycomorus.—This species is not very abundant. It grows on the edges of cliffs and at the entrances of caverns in the desert, and it is especially resistant to drought and alkali. I do not know that it has ever been tried as a stock, but I do not hesitate to recommend it for introduction and experiment.

Ficus sycomorus.—This tree (see figs. 5 and 6) deserves our attention. It is a native of India and grows all along the Palestine coast as far north as Beirut. It is very drought resistant, and in southern Palestine grows to a considerable size. Its wood is highly valued on account of its great density and the size of the trunks. It is used particularly to make sledges for thashing. But it is the use of the fruit as forage which should make it of value for certain parts of the United States. Although it is of inferior quality, it is greedily eaten by the Bedouins. The tree yields very abundantly, the fruit covering all of the old branches and even the trunk. It has several successive flowering periods, and the Arabs say that the "Djemeiz" gives seven harvests a year. The quantity of fruit yielded by a single tree is simply incredible, and the fruit, which is tolerably rich in sugar, would be in arid regions an excellent food supply for sheep and hogs. The tree grows well on dunes.

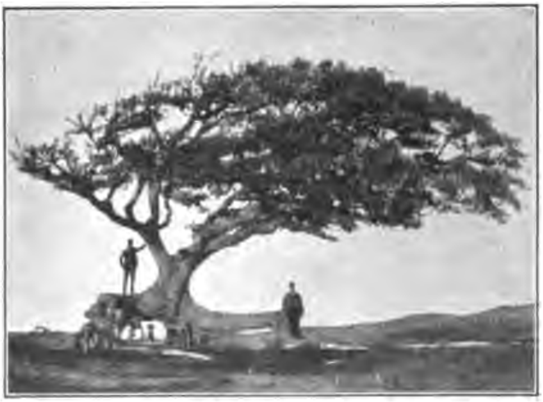


FIG. 5.—Fig tree (*Ficus sycomorus*) near Jaffa, showing its unusual resistance to drought. The roots are laid bare by the wind, and the branches on the windward side are checked in development by constant and strong sea breezes.

DATES.

At the present time date cultivation in Palestine is not of any great economic importance. But this has not always been the case. In biblical times Jericho, in the valley of the Jordan, about 600 to 700 feet below the level of the sea, was called the "City of Dates." At the beginning of the Christian era, when Tiberias and its environs were the Riviera of that time and when the princes and princesses of the Orient went there to spend the winters, the city of Magdala was celebrated, not only for its establishments for cleaning and dyeing the valuable costumes of its noble visitors, but still more for the delicious early dates which it produced.

To-day the cultivation of the date in the valley of the Jordan is of no importance whatever. Only the village of Abadieh still has a few date trees of a local variety, the fruit of which is of good quality. But the people who are establishing new plantations, instead of propagating this local variety, prefer to send to Egypt or Bagdad and bring from a distance and at great expense plants which are really of less value than the local product.

There are two places, however, where the old date plantations have not entirely died out. The first is east of the Dead Sea in the Valley of Zerka Maain, the ancient Calirrhoe, once celebrated for its hot baths, frequented by King Herod. Here thousands of date trees grow wild in crevices of arid sandstone 600 to 800 feet below sea level, in narrow gorges intensely hot and dry, where the soil is extremely alkaline.

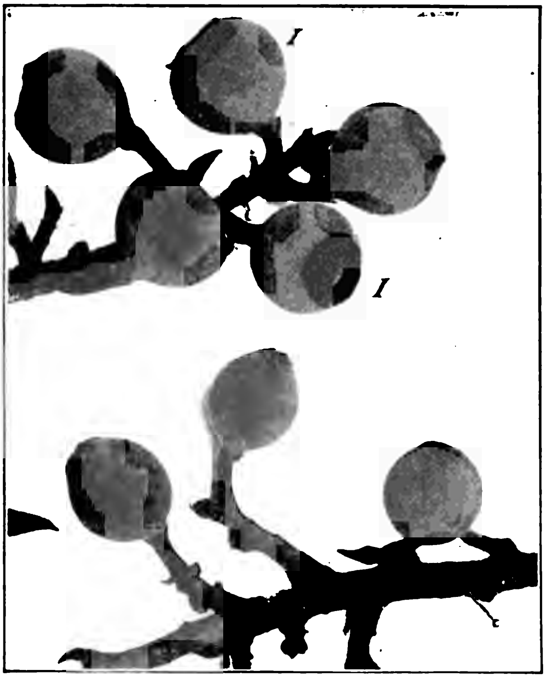


FIG. 6.—Fruit of fig tree (*Ficus sycomorus*). The Arabs in Biskra and Egypt cut off the tips of the immature figs in order to make them ripen. Three days after this is done the cut figs become twice as large as those uncut and develop a much better taste. The fruits marked "*I*" have been cut.

The second place is farther north, in the valley of the ancient Hieromax, 500 to 600 feet below sea level, in a marsh formed by several hot springs, with a temperature of 118° to 133° F. Here these wild dates form a veritable jungle, probably one of the few places of its kind in the world.

The historical accounts which vouch for the quality of the dates produced in these regions furnish proof that the cultivation of this fruit can be made profitable in such localities, and we may reasonably expect that the variety found in and around the valley of the Jordan may be of value for certain similar localities in the San Joaquin Valley.

Along the coast of Palestine, in sandy soils and on the edges of dunes, the date is here and there cultivated, especially in irrigated orchards and gardens. The ordinary varieties, however, do not ripen without artificial aid, and to this end the Arabs wrap the bunches of fruit in cloths soaked in vinegar. These cloths are kept constantly moist. When the wrapping of the fruit is discontinued the dates have changed from a black or chocolate color to an amber-yellow and have lost their astringent taste, the tannin having probably been rendered insoluble by the acetic vapor.[a]

It is probable, as suggested by Mr. Fairchild and Mr. Swingle, that the Japanese method of artificially ripening persimmons by putting them in barrels that have contained "saki" is based on this same principle, and that the astringency of the fruit is overcome in this case also by acetic vapor.

GRAPES.

Though the religion of the Mohammedans forbids the use of wine, they cultivate grapes extensively and have developed a great number of varieties. (See fig. 7.) Before the German and Jewish colonization began in Palestine, grapes were cultivated chiefly for table use and for raisins.

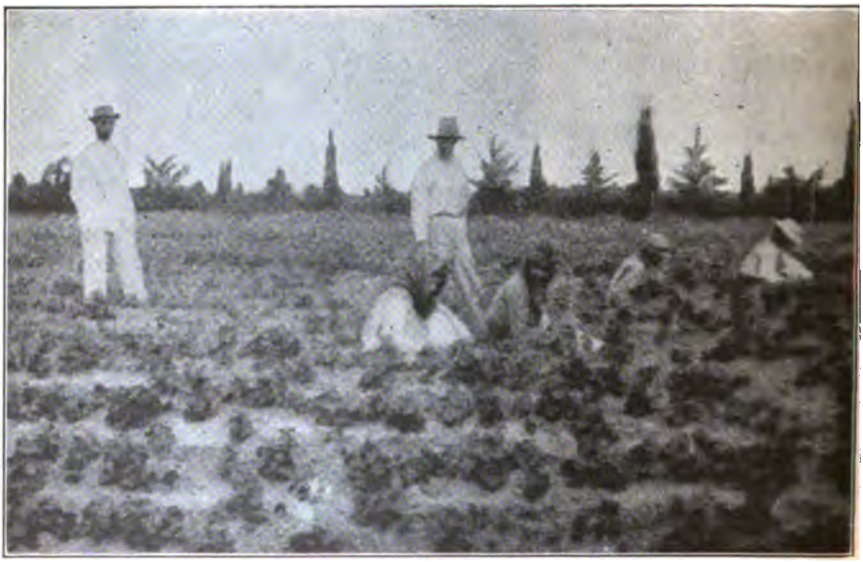


FIG. 7.—Commercial grape nursery at Hedera. The workmen, Russian and Koordistan Jews, can understand each other only in the Hebrew language.

For the most part the Mohammedans have propagated varieties that are not very juicy, having hard flesh and strong skins, as the fruit often has to be carried for days on the backs of donkeys or camels before it reaches its nomadic consumers or the people of far-distant villages. Our varieties are therefore rather distinguished for size, richness in sugar (habitually more than 18° Bé.), and good shipping qualities than for fineness of flavor. The grapes not eaten fresh are made into raisins, and the vicinity of Hebron, near Jerusalem, and more particularly of Es-Salt, in the Trans-Jordan, are the great centers of raisin production, producing about a hundred thousand dollars' worth every year. These places are at an altitude of more than 2,500 feet, and the grapes are grown on calcareous hillsides of Cenomanian and Senonian formation.

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[a] When I visited Tucson, Ariz., on September 27, 1909, I had the pleasure of explaining this process to Doctor Vinson, of the University of Arizona. He began immediately to experiment along this line, and I am very much gratified with the success secured by him. See report of his experiments in Science, n. s., vol. 30, no. 774, pp. 604–605. I believe that this process of artificial ripening ought to be experimented with in other States where, as in Arizona, there is difficulty in getting certain varieties of dates to ripen.

A study of the vineyards of Palestine would no doubt reveal many varieties that would be valuable to the United States. Mr. George C. Husmann, Pomologist in Charge of Viticultural Investigations, Bureau of Plant Industry, says that among the hundreds of table varieties with which he has been experimenting for years he considers the Palestinian "Dattier de Beirut" the best white grape and the "Purple Damascus" one of the best black varieties. And yet neither of these is among our finest Palestine sorts.

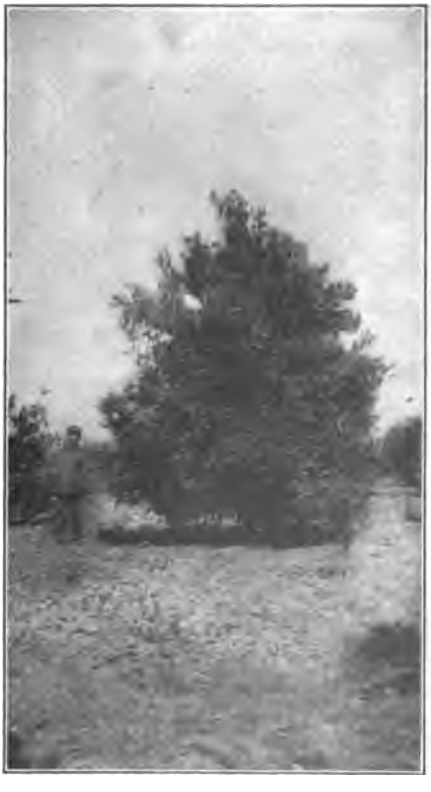

FIG. 8.—Seedling orange trees at Hedera, grown with a view to originating new varieties.

JAFFA ORANGES.

All of the crops mentioned have been cultivated for centuries in the Orient, but oranges were introduced there at a relatively recent date. (See fig. 8.)

Hasselquist, a pupil of Linnæus, who was the first naturalist to study Palestine, in the middle of the eighteenth century, speaks of the beautiful gardens of figs and pomegranates at Jaffa, but has not a word to say about oranges. This silence is significant. But at the time of Napoleon's Egyptian campaign, at the close of the eighteenth century, the orange was mentioned among the fruit trees. Chateaubriand, who traveled in the beginning of the nineteenth century, also speaks of this fruit. Lamartine, visiting Palestine in

October, 1832, praises the beauty and quality of the Jaffa orange, but speaks of having seen the flowers and the golden fruits at the time of his visit. Now, at this season of the year it was too late for the trees to have been in bloom and not late enough for the fruits to be ripe. This and other errors of observation cause me to doubt the value of the poet's description from the point of view of the naturalist and agriculturist, although its value as literature is unquestioned.

At any rate, in the second half of the nineteenth century the Jaffa orange was known in the markets for its superior quality. It was exported by sailing vessels all along the Syrian and Egyptian coasts. Its thick skin made it a good shipper, and it was carried as far as Constantinople and into Greece. It was not until 1875 or thereabouts that it was exported to England, while to-day Liverpool alone takes about 500,000 to 600,000 cases of the 700,000 or 800,000 that are annually exported.

I have not been able to learn the origin of this variety, which is cultivated only at Jaffa. In form it is very similar to the Malta orange, and it is possible that it is remotely descended from that variety; but it is not a blood orange, despite its marked affinity to that group.

The Jaffa orange is one of the largest, larger even than the Washington Navel. Its form is obovate, its skin very thick, and its fruit seedless. The tree is not spiny, and the fruit, therefore, is never scarred. Its shipping qualities are excellent. It is packed with very little care as compared with the methods used in California. The cases are thrown violently into the steamers, and they are often carried for three weeks without refrigeration and subjected to the greatest extremes of temperature; and yet the oranges reach the English markets in good condition and command good prices. It is at least a month from the time they are picked until they are purchased by the wholesale dealer, and during all of that time they are without cold storage.

Not only is this orange peculiar to Jaffa, but peculiar methods of cultivation and peculiar stocks are there in use.[a] The Schamouti, as the Jaffa orange is called, is generally grafted on a special sweet lime, which I have not found either in Africa (Algeria and Tunis) or in the United States. It is sometimes, though more rarely, grafted on the bitter orange (*Citrus aurantium*). This is not so well liked, because it requires more irrigation and is later in fruiting.

I must add that the Jaffa oranges which I saw in Tunis and Algeria and those grown in America and illustrated in American publications have very little resemblance to the real Jaffa orange. They are represented as having seeds, while the true Jaffa orange is seedless.

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[a] See Aaronsohn and Soskin, Die Orangengärten von Jaffa, Der Tropenpflanzer, Berlin, 1902.

Saida, the ancient Sidon, is another center of orange production. Many different stocks are used, and several varieties of oranges are known. Two of these are blood oranges, one called "Damaoui" (blood) and the other "Hutmali" (meaning "ringed," because it has a ring around the base). These two varieties are very popular. The "Beledi" (seedling) is also grown. This commonly yields three thousand fruits to the tree, and sometimes as many as five thousand.

FORAGE PLANTS.

Stocks and fruit trees are not the only interesting things in the Palestine flora. It contains some very valuable forage plants. This may seem to be strange in a country which suffers from a lack of forage, but this is due to the fact that the people do not cultivate the plants they have at hand.

The Leguminosæ must be considered first. In this family we find one of the most valuable forage plants in existence for semiarid regions, the importance of which for this purpose has not been sufficiently appreciated. This is the carob tree, sweet-pod, or St. John's bread (*Ceratonia siliqua*).

The carob tree is not, properly speaking, a native of arid, desert regions. It grows 20 to 25 feet in height, with a trunk as much as 40 inches in diameter. A tree 25 to 30 years old yields about 450 to 550 pounds of pods. I have seen wild stock, 15 or 18 years after grafting, that yielded 900 to 1,100 pounds of pods in good years, although a good average is 450 pounds to the tree. Counting twenty trees to the acre, this gives more than 8,000 pounds of pods to the acre. The pods contain 40 per cent of sugar—even more in good varieties—and 7 to 8 per cent of protein, so one can readily see why we rank it at the head of all forage plants.

An acre of carob trees upon arid soil yields a much greater quantity of food matter than an equal area planted with the best alfalfa. The food value of the carob has been known for a long time. It is the basis of the fodder of the English cavalry horses at Malta and of the horses belonging to the tramway company of Naples. It is among the chief exports from the island of Cyprus, and the growing of carob trees is one of the best sources of income on the island, for, once started, the tree continues to yield for many years. In this respect it is similar to the olive, which grows in the same localities, but it is generally admitted that the carob can not stand so arid a soil as the olive, as it requires more moisture in the subsoil. However, on this point also there are differences between the local races, there being some which will stand a considerable degree of aridity. There are several wild carob races and a few cultivated ones that should be tested by th Bureau of Plant Industry.

There are few crops so well adapted as the carob to agricultura conditions in certain parts of the United States. The tree demand little care, requires almost no pruning, does not need to be cultivate frequently, and has not so far shown any disease demanding treatment. It seems to me to be the ideal forage plant, as it gives a hig yield with very little labor. It should succeed in California and i parts of Arizona and Texas.

There are many of our Leguminosæ that should prove very interesting. We shall probably learn to value many species found amon the Galegeæ and Loteæ, and in the genera Vicia, Hedysarum, an Trifolium. For the sake of brevity I shall mention only one species

There are good reasons for believing that berseem (*Trifolium alexendrinum*) originated in Palestine, though we do not know definitel where it was first cultivated. But it grows wild there, as does als *Trifolium carmeli*, which differs from it only in slight botanical characters. Moreover, *Trifolium panormitanum* and *Trifolium supinum*, very closely related to *T. alexandrinum*, grow wild in Palestine. The fact that this whole group of closely related species grow wild in this region seems to indicate that they originated here. At any rate, the cultural value of these species needs to be studied.

Though berseem is a very valuable local plant, it is little cultivate by the natives, being grown chiefly by German and Jewish colonists It is sown with barley in the autumn along the coast, where the rainfall is as low as 14 to 16 inches per annum. It is of course grown without irrigation and gives two cuttings in the spring. In some very rainy years berseem yields three cuttings, or at least a good aftermath following the second cutting. After being pastured, the berseem is plowed under and forms an excellent green manure for a succeeding cereal crop. Egyptian berseem, grown under the same conditions of soil and climate, was found to be not nearly so good as our native races, and the latter should be carefully studied with a view to introduction.

I wish also to mention the Palestine saltbushes for alkaline soils, particularly *Atriplex palestina* and *A. halimus*, as well as *A. leucoclada*. The last grows from 3 to 6 feet high, but is so eagerly browsed by sheep and camels that it is difficult to secure even good herbarium specimens.

ANNUAL CROPS.

The greater the number of crops a farmer has, the greater the possibilities of crop rotation. Moreover, under such conditions he can farm with less risk than if he cultivated only a few crops and can make better use of his workmen, animals, machines, etc. So I think it is worth while to mention two crops practically new to the United States, the chick-pea or garbanzo (*Cicer arietinum*) and the sesame (*Sesamum orientale*).

THE CHICK-PEA AND THE SESAME.

Chick-pea.—The chick-pea (fig. 9) is one of the most valuable legumes grown in Palestine. It does not demand such careful preparation of the soil as sesame, and in good years it yields 12 bushels to the acre. It sells for as much as wheat, and often for more. It is therefore a remunerative crop and is excellently adapted for use as a rotation crop before wheat.

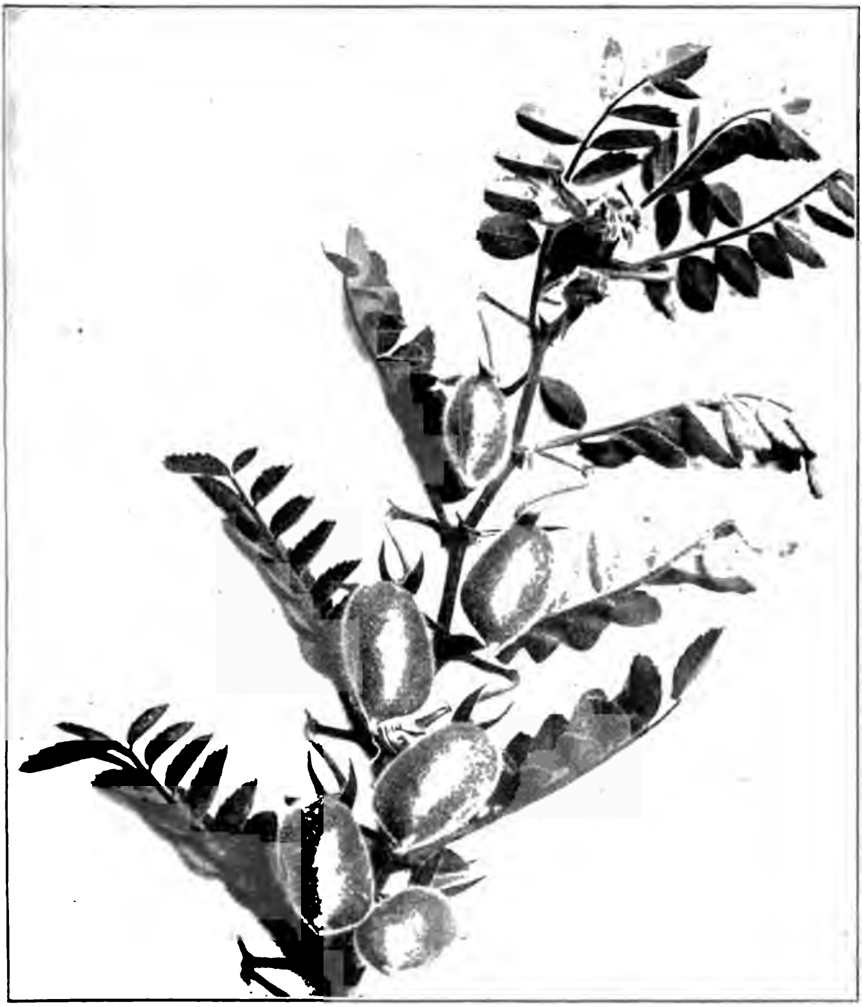

FIG. 9.—Branch of plant of chick-pea (*Cicer arietinum*), showing pods and white flowers. The variety with rose-colored flowers has black seeds, which are not so well liked as those of the white-flowered variety.

There are several sorts of chick-peas to be considered. Those o southern Palestine are different from those of central Palestine, an the plateaus of upper Galilee and farther north produce still different types. In the southern part of the country the chick-pea doe well with a rainfall of 16 inches or even less. I know from persona experience that these races do not grow well under irrigation. On th other hand, in the north there are races growing at 4,000 to 5,000 fee altitude, where the yearly rainfall is as much as 40 inches, which ar nevertheless liberally irrigated with water derived from the meltin snows of Mount Hermon.

As there are in Palestine no bean harvesters like those used i the United States, chick-peas are gathered by hand, the plants being pulled up by Arab women. The stems of this plant growin in southern Palestine are very corrosive and attack the hands o the workers. I have thought that it would be a good idea to introduce cultivated varieties from the Crimea and the Caucasus. Thes have erect stems, so that they can be harvested with mowers; they hav scarcely any corrosive quality and could be harvested by hand, bu can not resist drought. The leaves and stems of the Palestine chick-pea are corrosive because they are covered with crystals of oxalate and other hygroscopic salts which probably absorb to some exten the moisture in the air; so, no matter how dry the night may be, field of chick-peas always glistens with drops of water in the morning. Is it this condensation of atmospheric humidity which enable the plant to resist drought, while the Russian plant, not provide with this means for obtaining moisture, does not grow at all or give a poor yield?

The importance of choosing a race may be illustrated by anothe example. Some years ago a little Jewish colony was founded sout of Tiberias about 650 to 800 feet below sea level. The soil was gypsum marl, the annual rainfall about 1¼ feet. The Arabs ha cultivated only winter cereals, such as wheat and barley, assertin that no summer crop could grow there without irrigation. The cultivated chick-peas at Tiberias, but only in kitchen gardens. Thes latter were sown in winter in well-sheltered places, so as to profit b the winter rains. They came from Safed, scarcely 12 miles away, locality with twice as much rainfall and 3,300 feet higher in altitud I advised my brother, established in this colony, to try a variet of chick-pea not so well liked as that from Safed but coming fro a place where the conditions were more like his own. The succes of the first year surpassed all expectations. The neighboring colonists, seeing this, hastened to plant large areas with this chick-pea. feared that they were planting on too large a scale and tried t prevent their doing so. But their experiment was so successful tha the chick-pea is now one of the common crops of this colony, an every year some hundreds of acres are sown in this locality where five to seven years previously its cultivation was considered impossible.

The chick-pea will, I think, do well in the dry-farming regions of the United States, and if its cultivation is properly developed it should become a more important crop than the Lima bean.

Sesame.—The sesames of Palestine are of most excellent quality. In the markets of Marseille and of Germany they pay a special price for the Haifa sesame. This is preferred to the sesame of Jaffa or the Ghor (the Arab name for the valley of the Jordan), for at Haifa, as we shall see, a local race has been developed under quite different conditions.

The soil must be well prepared for sesame. For the best results it should be pulverized until "as fine as ashes." Sesame is generally sown about the time of the barley harvest—that is, about the end of April or the beginning of May, after the rains have stopped—for the Arabs have noticed that sesame germinates very irregularly if rain follows immediately after the sowing. They explain that this is because the oil in wet seed becomes rancid and therefore prevents germination. Although they have observed the fact correctly they have assigned a wrong interpretation. The real reason is that as after a rain a crust forms over the pulverized soil, the feeble sesame plants are not strong enough to break through it, so that the stand is irregular and too sparse. The Arab, who knows nothing about harrowing, does not know how to break up this crust. By harrowing we were able to sow sesame earlier and thus to have the benefit of the last rains. However, although the Arab tries to sow his sesame only after the rains, it grows as it gets sufficient moisture from water stored up in the soil.

South of Jaffa, where the rainfall is not more than 14 to 16 inches, the sesame is grown upon sandy clayey soils. At Haifa the rainfall averages more than 24 inches and sesame is grown on rich ground of volcanic origin, so that a very different race and one of a much better quality is developed there. In the valley of the Jordan the situation is still different. There, after barley or wheat has been harvested and the ground copiously irrigated, the sesame is sown on well-prepared soil. It grows without any further irrigation, under a torrid sun and in an alkaline soil, but here the reserve of water stored up in the soil is greater than at Jaffa or Haifa. We see, then, that under different conditions local races adapted to such conditions are developed, and this indicates to us how much care and study is necessary when we introduce new plants into strange surroundings.

I do not believe that under present labor conditions sesame can be profitably cultivated in the United States, because the plants of the crop do not all mature at the same time. This makes necessary several harvestings, always by hand. With the prices for labor no prevailing in the United States this would not pay. But, by mear of methodical selection, uniformity in the germination and maturin of these plants could easily be obtained.

I believe, therefore, that the chick-pea and the sesame deserve t be introduced into the semiarid regions of the United States an that they will furnish valuable aid to the farmer in the rotation o crops.

CEREALS.

Barley.—After having discussed the number and value of the loc races in other crops, little remains to be said regarding barley an wheat. There are, of course, in Palestine a great number of varieti of these grains. There are barleys belonging to the three botanic species *Hordeum distichon*, two-rowed barley; *Hordeum vulgar* ordinary six-rowed square-headed barley; and *Hordeum hexast* *chon*, the true six-rowed or club barley.

The species most extensively cultivated is *Hordeum vulgare pall* *dum*. Gaza barley belongs to this variety. It is cultivated i southern Palestine on lands of Cenomanian or of Pleistocene origi and where the annual rainfall is often not more than 10 or 12 inche It is much used for brewing in England. More than a millio dollars' worth is exported annually.

The barley of the Ghor or that of the Jordan is heavier and h the more regular grains characteristic of *Hordeum hexastichon*, th true six-rowed barley. It is a barley adapted to arid regions and t alkaline soils. The barleys cultivated on the vast steppes aroun Damascus belong principally to *Hordeum distichon*, or two-rowe barley.

Wheat.—Though the greater number of the cultivated wheats o Palestine belong to the group *Triticum durum*, this is not the onl group represented. Some belonging to *T. aestivum* and to *T. turg* *dum* are cultivated, especially in the northern part of the countr There are a great number of kinds of *Triticum durum*. At th little market of Haifa there are five or six different races. I sha mention only the "Nursy," the "Zeriin," and the "Dalaika," name after the villages which produce them.

The first has a long and rather thin grain and is splendidly adapte to low, humid, almost marshy soils. The wheat of Zeriin has large, full, white grain and is adapted to the hills of the Senonia limestone formation. The wheat of Dalaika has a small, transluce grain. It is a favorite in the markets and grows on soil of volcan origin, which is very fertile but subjected to such intense sunlight th no other variety can stand it.

Now, the three localities mentioned are hardly 10 miles from o another, yet each one has its special race. What is the significan f this fact? From the physical and geological nature of Palestine, s has been explained in the introduction, there necessarily resulted diversity of climates within a very small area, and this diversity f both soil and climate has given rise to a very rich and varied ora and fauna. In the cultivated plants a multiplicity of forms s also been favored by the political as well as by the natural nditions. The country has for centuries been divided among a umber of hostile tribes, each one living in a territory of quite efinite natural boundaries. The hostility of these neighboring ibes was so great that nearly all commercial relations were deroyed, the only interactions being those of warfare. Access to the arkets was thereby cut off, and the Arab learned to depend entirely pon the products of his own immediate district. As the same oducts continued to be cultivated for centuries on the same soils ithout outside introduction, local races were necessarily developed. hese conditions, which lasted for more than ten centuries in the rient, are finally rapidly disappearing.

From a human point of view we have every reason to rejoice at e pacification of the Orient, because of the greater safety to life d property and the better intercourse it has brought about; but om the standpoint of the cultivation of plants we are losing ground, r it is a natural tendency to reject all of the old habits and in so ing to annihilate many of these local races which have been in ocess of development for so many centuries. This can best be ustrated by the following example:

When the Jewish colony of Yemma was established at Dalaika, the lonists, who had no feeling of prejudice or hostility toward the rabs of Nursy and Zeriin, thought it would be an improvement to e up the small-grained Dalaika wheat and to introduce the fine, ge-grained wheat from Zeriin. The result, of course, was a failre, because the wheat introduced was not adapted to local climatic nditions. Instead, however, of correctly interpreting their failure, me of the colonists attributed it to the use of European plows, and hers to American harrows, both of which had been recently imrted. (See fig. 10.) I enter into these details in order to show the lue of the local products which the Orient has developed during the nturies of stagnation, and also to point out the danger of the deruction of these races of plants in consequence of the general levelg which is a necessary accompaniment of national awakening and ogress. An early botanical-agronomic exploration of the Orient therefore necessary. The sooner it is made the greater will be the ances for obtaining valuable races of plants.[a]

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[a] The importance of this point has been emphasized by A. F. Woods. See ence, n. s., vol 26, no. 669, pp. 541–543; also Report of the National Conration Commission, vol. 3, 1909, pp. 146–150.

MEDICINAL AND MISCELLANEOUS PLANTS.

In the preceding pages I have referred only to crops which can extensively cultivated and promise to be of considerable econom importance. But there is a host of plants of secondary importa which ought also to be mentioned.

For example, in the Cucurbitaceæ we cultivate *Cucumis me* *Citrullus vulgaris* (watermelon), *Cucumis chate*, and *C. m* *dudaim.*

Of the different races of watermelon cultivated in Palestine shall mention only two. The "Abu-taba" (father of the ring), called because of the large scar which it has in the place of the pist is cultivated chiefly along the coast in the neighborhood of the Je ish colony Hedera. It is exported to the value of $200,000 annua (see fig. 11), chiefly from Cæsarea and Minet Abu-Zabura. T latter is a temporary harbor maintained only during the shippi season of these melons. This Abu-taba, which grows on the poore soil, is very early, and because of its thick rind it is uninjured journeys of two to three weeks. It is therefore shipped to Egyp Smyrna, and Constantinople.

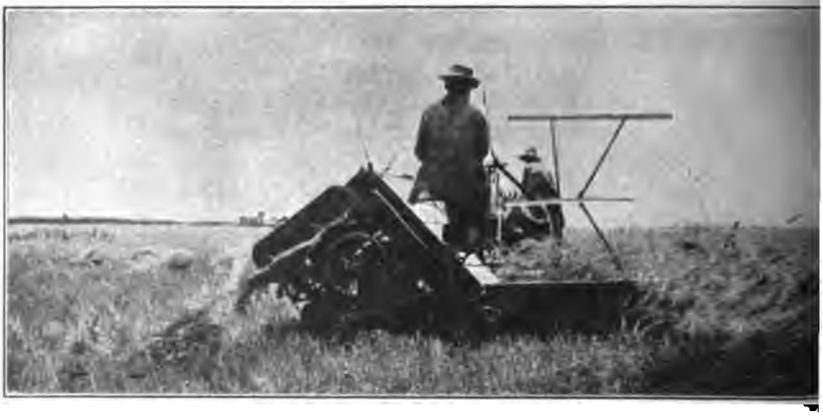

FIG. 10.—An up-to-date Jewish farmer in the dry-farming region of the Jordan Val using an American-made binder.

Another rather curious sort is that cultivated in the neighbo hood of Tiberias. It is not so early as the one just mentioned a does not have such good shipping qualities, but it is much liked account of the sweetness of its fruit. It is very small, being on about the size of a grapefruit.

There is a kind of muskmelon, cultivated chiefly by the Bosnia in Cæsarea, that is kept until late in the winter. It is, I believ derived from the sort cultivated at Kirk-Agatch, in Anatolia, variety propagated in California under the name "Casaba."

I may also mention *Citrullus colocynthis*, a medicinal plant. The fruit grows wild and is gathered for export, chiefly to the United States. The region in which it grows best is a sandy desert between Gaza and El-Arish.

There are other wild plants useful as vegetables, etc.; for instance, *Gundelia tournefortii*, the "Akub" of the Arabs, which grows wild in rocky localities. Its white, juicy shoots are gathered by women and eaten like artichokes. Cargoes of this plant are shipped along the coast from the rocky regions around Haifa, particularly to Beirut. It is a very good vegetable and worthy of recommendation. Its leaves are somewhat spiny when fully developed, but by selection this slight defection could easily be overcome.

FIG. 11.—The watermelon market at Jaffa.

I may also mention the wild *Cynara syriaca* and *Cynara auranitica*, closely related to the cultivated artichoke. The former grows in the damp soils of the low plains along the coast; the latter in the deep, dry soils of the high plateaus of the Trans-Jordan. Their improvement and their use for crossing are to be recommended.

Among the plants particularly adapted to desert regions is *Tamarix articulata*, the "Athl" of the Arabs. Its galls are used for tannin. It grows well in sand dunes and has been successfully cultivated in southern Tunis. This tree is easily propagated by cuttings and appears to me to be well adapted to the southwestern United States.

Another desert plant, *Calligonum comosum*, resembles *Zizyphus lotus* in its habit of growth. It is even more useful than the latter for the fixation of sand dunes. It sends out roots 65 to 100 feet be discovered, there was a small group of the most distinguished botanists who maintained not only that such a prototype existed but that they already had it in their possession. In 1873 Körnicke, when preparing the notes for his standard work on the cereals,[a] had discovered in the herbarium of the National Museum of Vienna, among the stems of *Hordeum spontaneum* which Kotschy had gathered at Rasheyya, on the northwestern side of Mount Hermon, in 1855, part of an ear of a graminiferous plant which he considered to be a wild wheat and which resembled the emmer (*Triticum dicoccum*). But, with an unaccountable forgetfulness, Körnicke did not speak of this discovery in the work mentioned, which appeared in 1885, and it was not until 1889, at a meeting of the Society of the Lower Rhine and Westphalia, that he reported his discovery.[b] At that time he named Kotschy's plant *Triticum vulgare dicoccoides* and declared it to be the prototype of the cultivated wheats. Afterwards Körnicke returned repeatedly to the discussion of the question, urging all botanists who went into the region of Mount Hermon to give their attention to the subject and trying to induce the scientific academies of Vienna and Berlin to organize an expedition for that purpose. His efforts, however, were in vain.

In 1902 Ascherson and Graebner published their "Synopsis of the Middle European Flora." In this work, in the monograph dealing with the Tritici, they set forth Körnicke's views, which thus reached a large public. In order to understand why Körnicke believed that Kotschy's plant represented the wild prototype of wheat, it is necessary to know something of the conclusions he had reached regarding the classification and development of the genus Triticum, which includes wheat and several closely related grasses.

BOTANICAL CLASSIFICATION OF WHEATS.

In the work just mentioned, which adopts the excellent classification of Körnicke in its essential features, but also takes into account the investigations of Hackel, the wheats are classified as follows:

In the section Eutriticum there are three species—*Triticum monococcum* (einkorn), *Triticum polonicum* (Polish wheat), and, thirdly, a collective species, *Triticum sativum*.

Triticum sativum is divided into three small species:
- *Triticum dicoccum* (emmer).
- *Triticum spelta* (spelt).
- *Triticum tenax* (common wheats).

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[a] Körnicke and Werner. Handbuch des Getreidebaues. 1885.

[b] Verhandlungen des Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens, und des Regierungs-Bezirks Osnabrück. Bonn, 1889.

One of these, *Triticum tenax*, is in turn subdivided into subspecies:
Triticum vulgare (wheat). [*Triticum aestivum.*]
Triticum compactum (short-eared wheat, club wheat).
Triticum turgidum (Poulard wheat).
Triticum durum (durum wheat).

This classification is essentially artificial, and the distinctions between the groups are very difficult to maintain. Near the close of Körnicke's life, after having made a specialty of this study for forty years, he declared that it was almost impossible to distinguish between some forms of *Triticum durum* (subspecies of *T. tenax*) and *Triticum dicoccum* (small species of the collective species *sativum*).

The behavior of crosses and hybrids also indicates a very close relationship among the so-called species. Thus, Vilmorin crossed *Triticum aestivum* and *T. durum* and obtained a *T. spelta*. *Triticum polonicum* occupies a somewhat unique place on account of its long glumes, but it hybridizes with the other species and is regarded itself as only a hybrid. *Triticum monococcum* alone holds a place entirely distinct from all of the others because of its refusal to hybridize with the rest. In fact, all of the other species pass so gradually into one another that it seems more than probable that all of the wheats belong to one species.

THE BRITTLE RACHIS OF THE PRIMITIVE CEREALS.

What can we suppose the prototype of wheat to have been, and by what characters can it be recognized? A fragile rachis was undoubtedly one of the characters of this wild prototype. All who have studied the question agree as to this. All agronomists and all botanists regard a rigid rachis as an acquired characteristic, developed by man under cultivation and having a tendency to destroy the plant's natural capacity for dissemination.

All of the genera and species related to wheat, as Aegilops, Agropyron, etc., have this fragile rachis, a necessity in order that the grain be assured a wide dissemination. It is also needful that the grain remain fixed in its glumes as a general protection against premature germination, decay, and destruction by enemies. But this characteristic, so useful to the plant itself, was a drawback to its use by man. Wheat with a brittle rachis requires to be harvested before complete maturity and is difficult to handle. Moreover, grains that are held too closely in the glumes can not be thrashed with flails, but a special system of mills must be used. In Egyptian tombs 6,000 years old have been found heaps of emmer hulls, a careful inspection of which clearly indicates that they were thrashed by such mills, so that their use must date from the most ancient times.

Wild wheat, the same as wild oats and wild barley, must have been provided with the means for ready dissemination. Man, however,

Triticum monococcum with any other wheat. Later, Beyerinck succeeded in producing the cross, but the products were strict hybrids; that is, they were all sterile. More recently still, Professor von Tschermak, who took up Vilmorin's experiments, met with the same failure. He has succeeded in crossing *Triticum monococcum* with *Triticum ovatum*, which, as we have seen, may in turn be crossed with *Triticum aestivum;* but neither he nor anyone else has succeeded in crossing *Triticum monococcum* with any other wheat.

Let us note, however, that in the case of *Triticum polonicum* there was difficulty in crossing, because of the peculiar form of its glumes, until a particular operative technique had been worked out. In view of this we may question whether the failure with einkorn was not also caused by a faulty technique. We may remark in this connection that, as Doctor Trabut observed,[a] no one has ever succeeded in crossing the two varieties of *Anagallis arvensis*, *caerulea* and *phoenicia*, although the only difference between the two is that the former has blue and the latter pink flowers. But we can not on this account class them as distinct species.

In so far, therefore, as the lack of sexual affinity between two related forms justifies us in recognizing in them two different species, *Triticum monococcum* must be considered as standing alone, and it can not be ranked as the progenitor of the cultivated wheats.

From the historical point of view, also, we may reject einkorn as the progenitor of wheat. Its cultivation can not have gone back to very ancient times, since the cultivated form differs so little from the wild one. The only evidence that we possess of any antiquity is that Schliemann discovered it in his celebrated excavations of ancient Troy, showing that it was cultivated there. But the other cultivated wheats are traced back for thousands of years before this.

Spelt and emmer, then, are the only two forms remaining to be considered, but we have no ancient remains of the cultivation of spelt, nor is there any mention of it in literature until toward the beginning of the Christian era.

EMMER THE ONLY POSSIBLE PROTOTYPE OF TRUE WHEAT.

The species of grain of the cultivation of which we have the oldest records is emmer. It is true that durum wheat has been found in Egypt in some tombs of the first dynasty—that is, four thousand years before the Christian era—but emmer is found both in far greater abundance and in all of the tombs. It is not at the present time cultivated anywhere in Egypt, durum wheat having since historical times taken its place.

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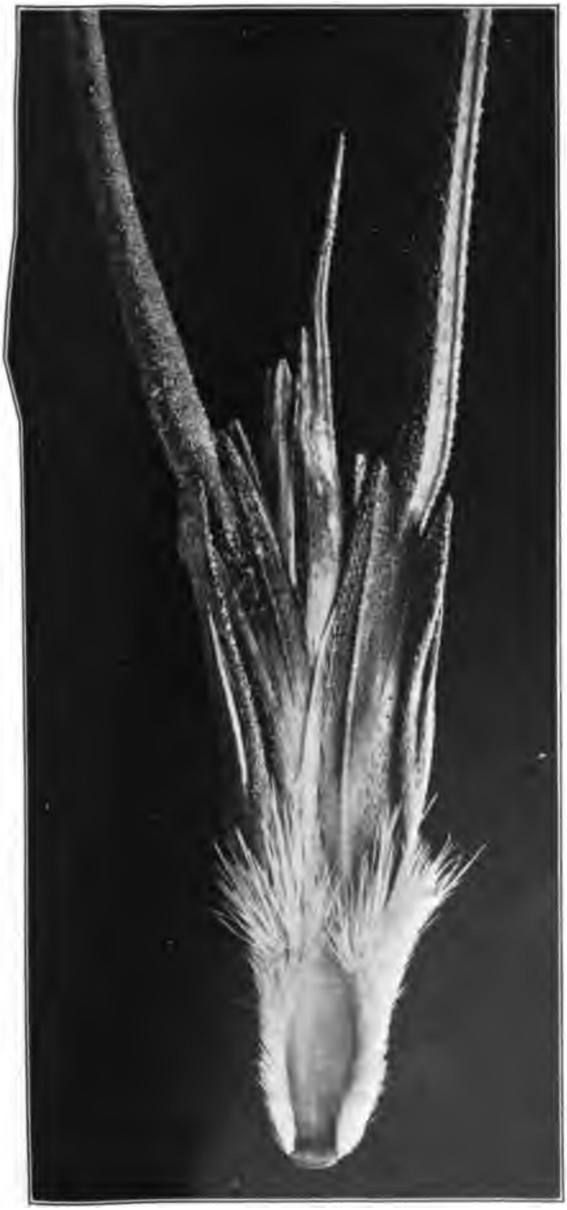
[a] Bulletin de la Société Botanique de France, vol. 68, p. 182.



UPPER FACE OF SINGLE SPIKELET OF TRITICUM DICOCCUM DICOCCOIDES.

(Enlarged about 5 diameters.)

to demonstrate to him the Eocene origin of the ground. Suddenly I noticed in a crevice of a rock of nummulitic limestone an isolated plant which at first sight looked like a stool of barley, but which on closer inspection proved to be a wheat, the ripe spikelets of which could be detached from the brittle rachis by the slightest shake. I could hardly believe that it was really the plant for which I was looking. The development of the head and grains was so perfect—so nearly like the forms produced under cultivation at the present day—that I could scarcely believe that this was their wild prototype, though, to be sure, if it had not been so well developed primitive man would not have noticed it, or at least would not have appreciated the importance of its cultivation to such an extent as he did.

I could not at that time remain longer at Rosh Pinar, and so left the next day for the north. On the way from Rosh Pinar to Rasheyya (three days on horseback) I looked for wild wheat, but could not find any. At Rasheyya, too, I spent a great deal of time botanizing in the vineyards in the hope of finding the Triticum there, but also without success. But when I began to extend my search to uncultivated lands, along the edges of roads and in the crevices of rocks, I found a few stools of the wild Triticum. Later I came across it in great abundance, and the most astonishing thing about it was the large number of forms it displayed. The sample specimen from Rosh Pinar, however, was the finest one. This plant had made a very vigorous growth and bore heads the stiff, rugose awns (beards) of which were nearly or quite 6 inches long. (See Pls. II, III, and IV.) At the foot of Mount Hermon the stems were longer but fewer. Instead of being 2 feet high, as at Rosh Pinar, this wild wheat at Rasheyya was more than 40 inches high.

I ascended Mount Hermon and went around to the other side. I intend at some future time to describe this trip, as its botanical and geological results may interest the scientific world; but here I shall speak only of the Triticum. In descending from the summit of Mount Hermon (9,498 feet in altitude) toward Arny, a little village on its eastern slope, I found innumerable forms of this wild Triticum growing in abundance at an altitude of 5,250 feet and less. (See Pl. V, fig. 1.) In some cases the whole ear was black; in others only the glumes or part of the glumes; in still others the awns alone were black. Sometimes the glumes were completely glabrous (see Pl. VI, figs. 1 and 2), sometimes very hirsute (see Pl. VII, fig. 1); in some the form of the glume resembled that of *Triticum durum* (see Pl. VI, fig. 2), in others the development of the secondary nerve was similar to that of *T. monococcum.* (Compare Pl. VIII, figs. 1, 2, and 3.) I had discovered so many forms that no attempt at determination could be made. Among these was even *T. monococcum aegilipoides* (see Pl. VII, fig. 2), a form I had not at all expected to find. I could therefore only gather specimens, noting their habitat, associations, etc.

As soon as I got home I wrote the good news to my friends in Berlin. A short notice of the results of this trip and an article by Professor Schweinfurth on the importance of this discovery and on the possibilities which it opened up were published.[a]

My trip of 1906 merely established the native habitat of *Triticum dicoccum dicoccoides*. It was still necessary to find out the extent of the distribution, its habit of growth, etc., and I made another trip for this purpose in 1907. The principal results of this trip relating to problems of the cereals in their wild state have been published, with an introduction by Professor Schweinfurth[b] and an appendix by Professor Ascherson, in the proceedings of the Botanical Society of Berlin.

On this trip I was able to show conclusively that *Triticum dicoccum dicoccoides* is indigenous to the regions of Mount Hermon and the northern part of the Trans-Jordan. The idea that it is a plant escaped from cultivation can not be entertained for a moment. In the first place, *Triticum dicoccum* is not cultivated anywhere in Syria and Palestine. I have not been able to discover any hybrid or mongrel between this wild wheat and the cultivated forms. Second—and this is the important point—our *Triticum dicoccum dicoccoides* rarely appears on soils which have been cultivated for any purpose. It grows only upon the slopes of the most arid and rocky hills and in places exposed to the hottest rays of the oriental sun.

DIVERSITIES OF WILD EMMER.

The number of forms of *Triticum dicoccum dicoccoides* which I gathered in 1907 is astounding—" verblüffend," to use Körnicke's own expression. I found specimens in which the glume had a secondary tooth (compare Pl. VIII, figs. 2 and 3), produced by the great development of the secondary nerve, which constitutes a morphological resemblance to *Triticum monococcum*. And, on the other hand, I found forms of *T. monococcum aegilipoides* with the secondary tooth less developed than any that Körnicke had ever seen. We may presume that these were transitional forms.

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[a] See Aaronsohn, A., and Schweinfurth, G., Die Auffindung des wilden Emmers (Triticum dicoccum) in Nordpalästina, in Altneuland Monatsschrift für die wirtschaftliche Erschliessung Palästinas, Berlin, July–August, 1906, nos. 7–8, pp. 213–220; also Prof. Dr. G. Schweinfurth in Vossische Zeitung, September 21, 1906, and in Annales du Service des Antiquités de l'Égypte, 1906.

[b] Schweinfurth, G., Ueber die von A. Aaronsohn ausgeführten Nachforschungen nach dem wilden Emmer (Triticum dicoccoides Kcke.). In Berichte der Deutschen Botanischen Gesellschaft, 1908, vol. 26 a, pt. 4, 1908, pp. 309–324.

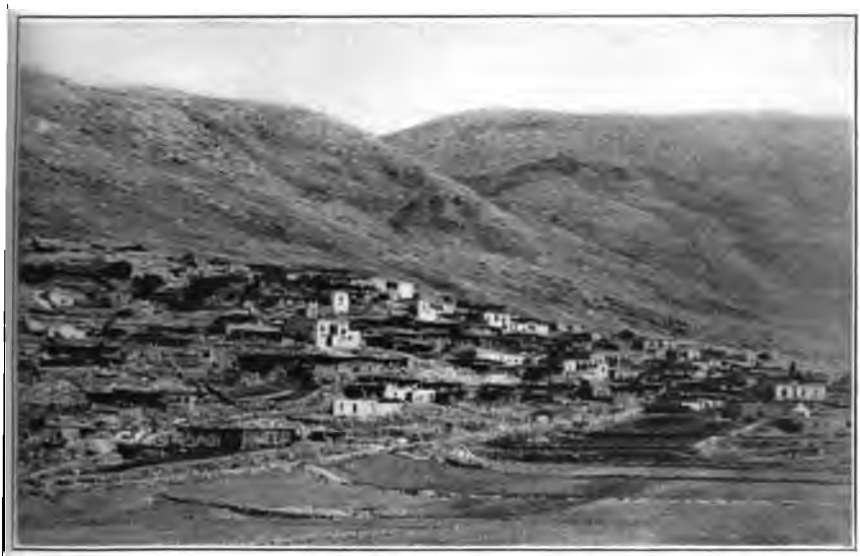

FIG. 1.—VIEW OF MEJDEL ESH SCHEMS, ON THE SLOPES OF MOUNT HERMON, WHERE WILD WHEAT WAS FOUND.

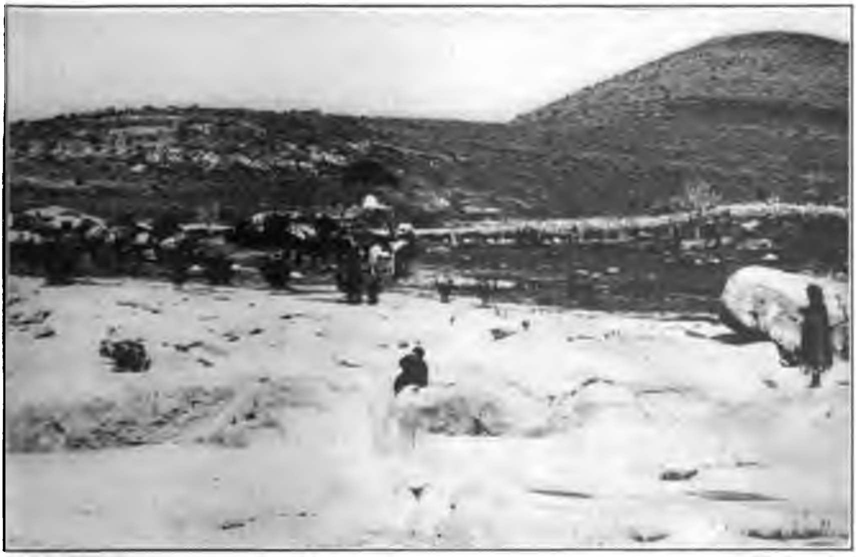

FIG. 2.—SCENE IN WADY WALEH, SHOWING THE WRITER'S CARAVAN. WILD WHEAT AND BARLEY GROW ON THE ROCKY HILLS.

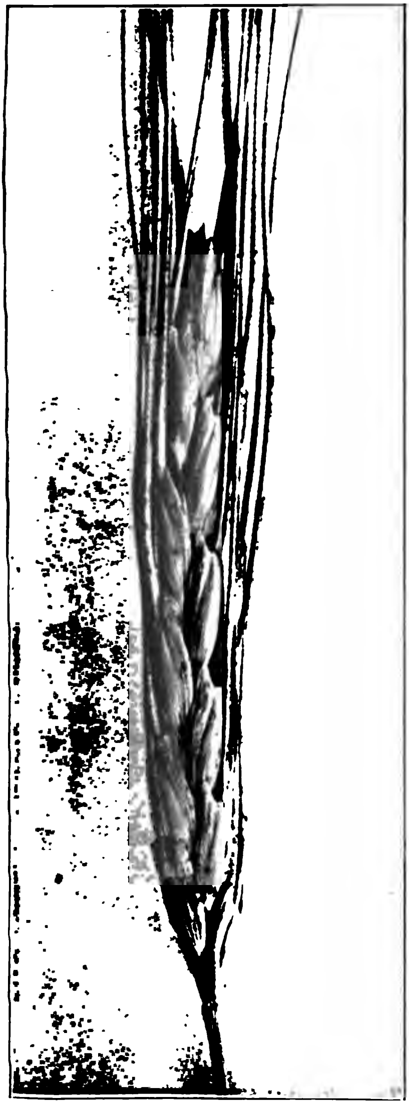

FIG. 1.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING LONG GLUMES; A TRANSITIONAL FORM TO T. POLONICUM.

(Natural size.)

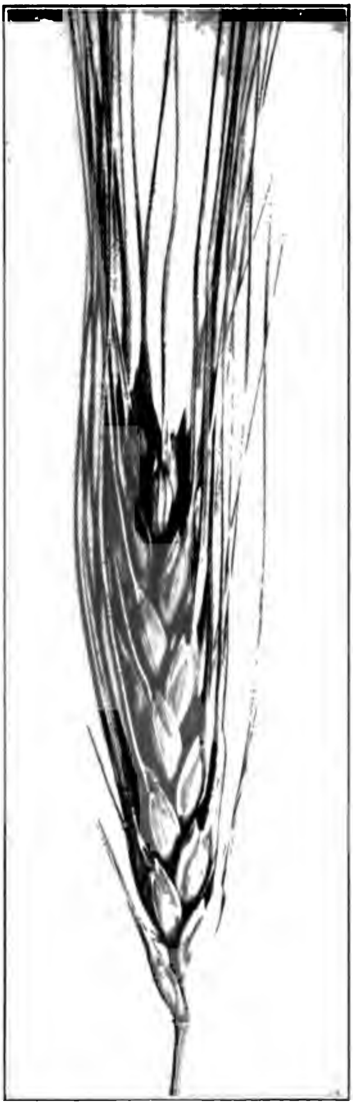

FIG. 2.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING GLUMES RESEMBLING THOSE OF DURUM WHEAT.

(Natural size.)

I discussed this subject with Körnicke. A year before he had said that certain forms which I had labeled *T. monococcum* were really *T. dicoccum dicoccoides*, and vice versa. But after a minute study of these forms he took pleasure in acknowledging that my determinations were correct, stating this both in his letter to Professor Schweinfurth, dated December 31, 1907, and in his letter to me written a few days before his death.

HABITUAL ASSOCIATION OF WILD EMMER WITH WILD BARLEY.

Another observation of some importance made by the writer is the following:

The wild emmer is always found in company with wild barley. The latter has perhaps a greater area than the former and occasionally is found where wild emmer does not grow, but it is very unusual to find the emmer unmixed with the barley.

Now, it has always been difficult to say whether barley or wheat is the older crop. The oldest writers always speak of these two together, and in excavations in Egypt and elsewhere they are always found associated. Körnicke has asserted that the cultivation of barley is older than that of wheat. But why may we not assume that our prehistoric ancestors began the cultivation of the two cereals simultaneously and that they grew barley and wheat together just as they are found growing when wild? The habits of these two plants are so similar that the Arabs fail to distinguish them, although they are given to more or less close observation of natural phenomena. Several times I have asked the Arabs to gather for me some stools of wild Triticum like the sample which I gave them. They always brought me back *Hordeum spontaneum.* Nor have I been able to find any special word in their language for wild wheat. They always called it "scha'ir barri" or "scha'ir iblisse" (wild barley or devil's barley). But when I asked if it was not wild wheat, they admitted that it was "kamh barri" (wild wheat), being eager, as the Arab always is, to agree with the opinion of a guest.

DISCOVERY OF RYE, BOTH WILD AND CULTIVATED, IN SYRIA.

On my 1907 trip I was able to demonstrate that *Triticum dicoccum dicoccoides* and *Triticum monococcum aegilipoides* are indigenous to the vicinity of Mount Hermon; to study their distribution, their preferences as to location, and their habits of growth; and to gather a number of intermediate forms, and to study their association with each other and with *Hordeum spontaneum.* But, in addition to this, I made another discovery which I should like to mention.

I found some stools of cultivated rye (*Secale cereale*) at Damascus in a field of wheat. Now, two days later at Zebedani, on the Anti-

Lebanon, I gathered a stool of *Secale montanum.* It is an interesting fact, too, that the wheat in which the cultivated rye was found was *Triticum durum melanopus* (*T. complanatum*), having a starchy and not a glassy grain.

Now, it has been asserted as a fact that in ancient times as well as in our own day rye has been unknown to the Orient. Philologists were ignorant of the special name for this cereal in the Orient, and they therefore concluded that rye must have originated in Europe. It was on this theory that Hoops, Much, and others based their conviction that the cultivation of the cereals originated in Europe. No one who knows how strongly Damascus has resisted European influence, even up to the present time, can for a moment believe that the rye which I found in the wheat field had been imported. It is to be noted, too, that the region to the east and the north of Damascus is almost unexplored, and it may therefore be that without our knowledge rye is more or less cultivated there. I have not yet found out the special name the Arabs use to designate this cereal.

WIDE RANGE OF WILD EMMER.

In 1908 I was commissioned by the Turkish Government to make a scientific exploration around the Dead Sea, and was thus enabled to extend my study of *Triticum dicoccum dicoccoides.*

While descending Engedi, on the western shore of the Dead Sea, in March, 1908, I noticed a plant of *Hordeum spontaneum* with unripe heads, but gave it no particular attention. On March 26, having gone around the Dead Sea to the south and having pushed tolerably far into Arabia, our caravan reascended from El-Mazra-a on the southeast shore of the Dead Sea, 1,300 feet below sea level, toward the plateau of Moab, which is in some places more than 3,300 feet above sea level. At 350 to 500 feet above the Dead Sea, where the salty marls began to give place to calcareous strata, we saw *Hordeum spontaneum* more and more frequently. The abundance of this and the conditions of soil and vegetation made me think at once of the wild emmer. But, though I looked carefully, I could not find it either that day or on the three following days, although wild barley was as plentiful as before. I attributed this to the season, for the barley had barely headed and the wild emmer, if there, would have been concealed. On March 28 we camped in the Wady Waleh (see Pl. V, fig. 2), with which we were familiar from a preceding exploration around the Dead Sea and where, on February 29, 1904, Professor Blanckenhorn and I had discovered flint implements from a paleolithic, or perhaps even an eolithic, epoch at the foot of the rude stone columns called "menhirs," some of which were overturned and some still standing (see fig. 12).

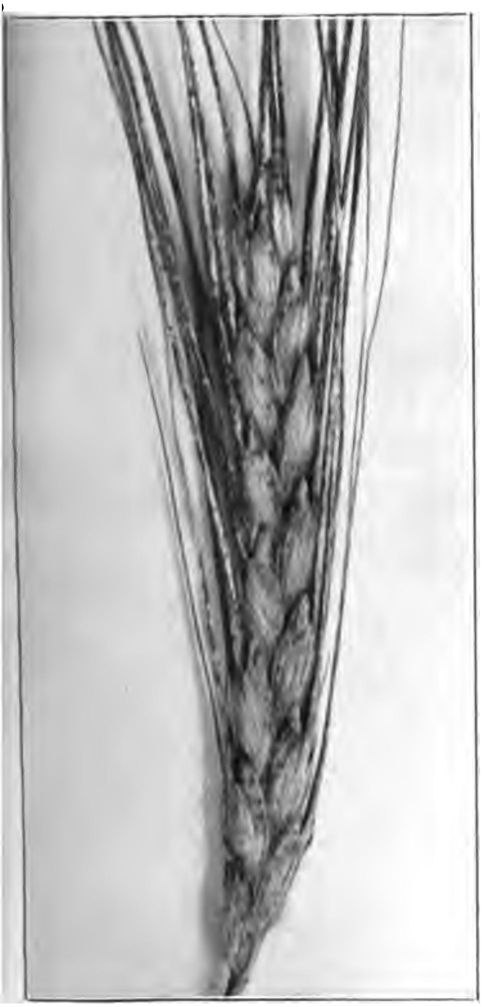

FIG. 1.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING LONG GLUMES; VERY HIRSUTE.

(Natural size.)

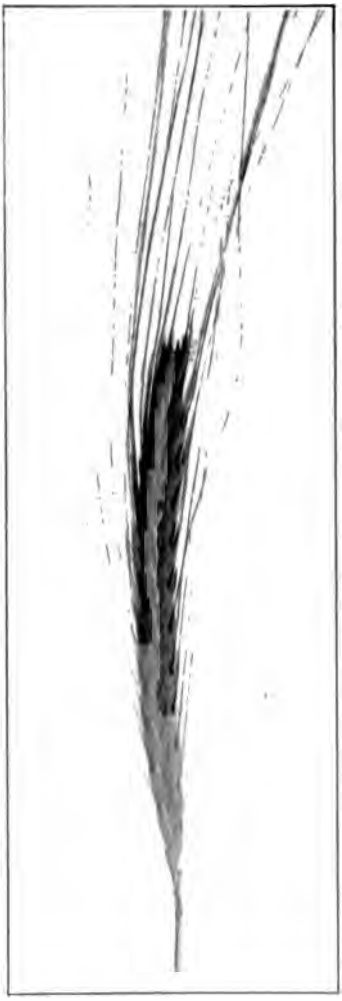

FIG. 2.—SPIKE OF TRITICUM MONOCOCCUM.

(Natural size.)

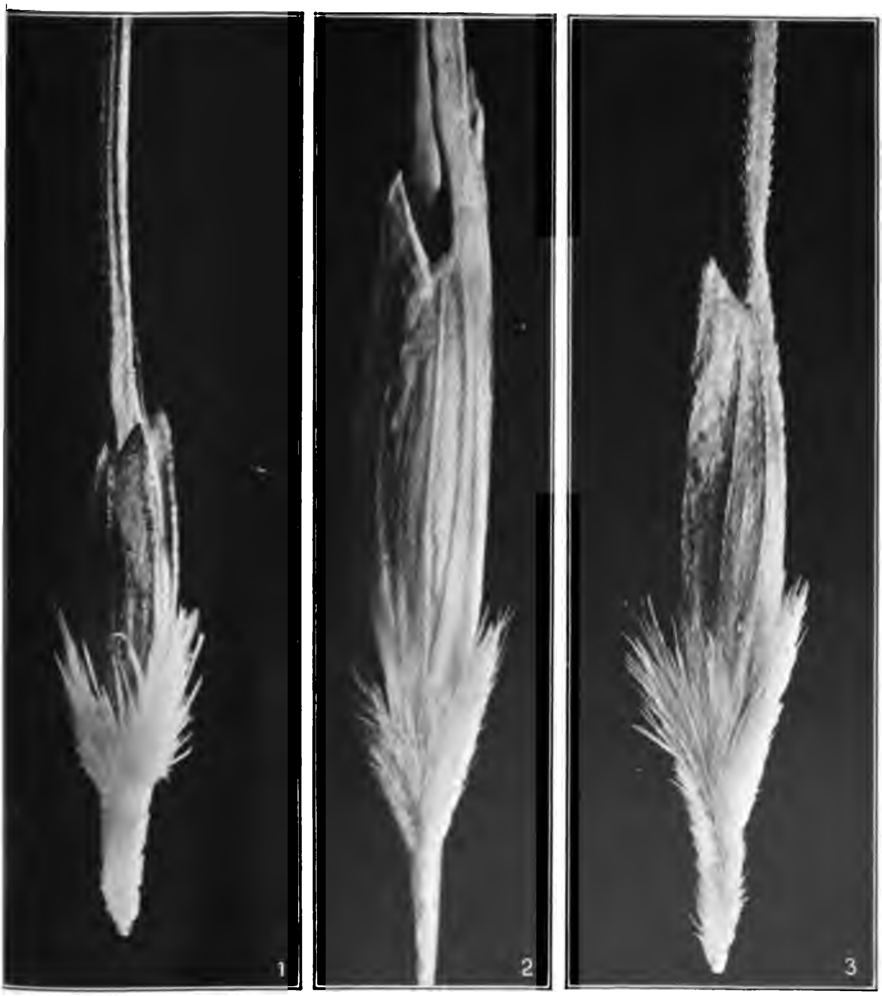

Fig. 1.—Spikelet of Triticum monococcum, Showing the Characteristic Secondary Tooth of the Glume. Fig. 2.—Spikelet of Triticum dicoccum dicoccoides, Showing the Secondary Tooth, as in T. monococcum. Fig. 3.—Spikelet of Triticum dicoccum dicoccoides, Showing the Absence of the Secondary Tooth of the Glume.

(All enlarged 4 diameters.)

At this latter visit the hills which bordered the Wady Waleh were so abundantly covered with wild barley that they and the valleys looked like fields of cereals sown irregularly and infested with weeds. I tried to picture in my mind the life of our prehistoric ancestors who lived on the banks of this delightful wadi (canyon). I believe, as does Eduard Hahn, that our ancestors were not exclusively hunters and shepherds, as they are generally supposed to have been. They were without doubt chiefly vegetarians, and in this region, where the growing season is very short, they must have learned at a very early date to gather and preserve grain. Their life here must have been a comparatively enviable one. The negroes of Africa are compelled to make bread from a species of Pennisetum and from certain Poas, which are very hard to harvest; the peoples of the Sahara with great labor secure a coarse bread from the seeds of *Panicum turgidum* and of *Aristida pungens*, which latter is even in our day an article of commerce; the Touaregs live on the seeds of different Diplotaxis, *Eruca sativa*, *Senebiera lepidoides*, and other crucifiers; the Tibbus, of Siwah, live on bread made from the seeds of colocynth.[a] When we think of what these and other peoples of our own day have to use for food, we must acknowledge that the prehistoric inhabitants of the valleys and plateaus of the Trans-Jordan were to be envied when they had *Hordeum spontaneum* and, as we anticipated, *Triticum dicoccum dicoccoides* also in abundance. (See Pl. IX, figs. 1 and 2.)

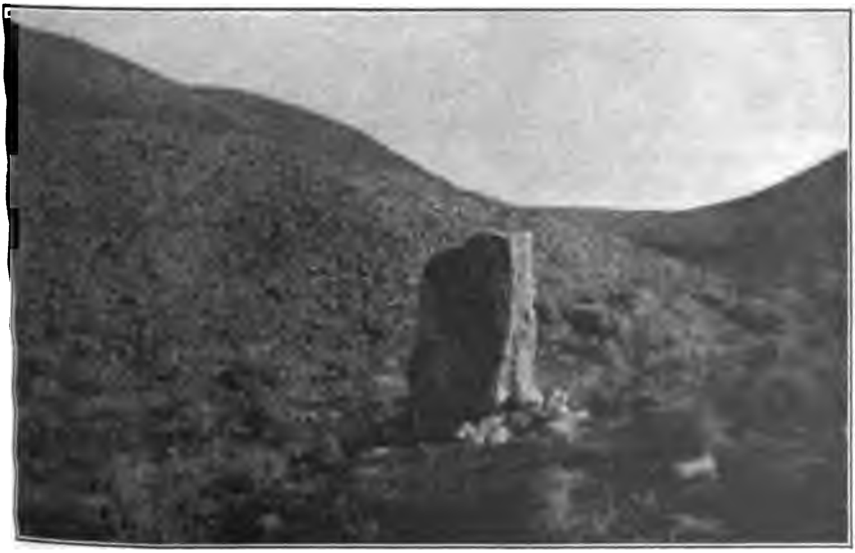

FIG. 12.—Monolith in Wady Waleh. At its foot paleolithic or eolithic flint implements were found. Wild wheat and barley were found on the hills in the background.

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[a] See Duveyrier, Les Touaregs du Nord, p. 204; P. Soleillet, L'Afrique Occidentale, p. 177; and Nachtigal, Sahara und Sudan, vol. 1, p. 249.

Everything here seemed to be favorable to the growth of the wild emmer. So, when I returned to Jerusalem in April, I communicated to Professor Schweinfurth my hypothesis that *Triticum dicoccum dicoccoides* grew in the country of Moab, as he continued to take an interest in my travels and has called my attention to a number of problems which otherwise would have escaped me. I resolved to return to the country of Moab at a more favorable time, in May, for example. My joy was unbounded when, on returning to the country of Moab and Gilead two weeks later, April 17, 1908, I found *Triticum dicoccum dicoccoides* while going from Tell Nimrin, in the valley of the Jordan, to Ain Hummar, on the plateau of Es-Salt. A little later it was found as plentifully as it had been in the neighborhood of Mount Hermon.

SOILS AND LOCATIONS PREFERRED BY WILD EMMER.

I may summarize my observations on *Triticum dicoccum dicoccoides* as follows: It is always found in the same sort of habitat—in the crevices of rocks, in places where the rocks are covered with only a thin layer of soil, in the most arid situations and those most exposed to the sun (see Pl. I, fig. 2, and Pl. V, figs. 1 and 2), and always associated with *Hordeum spontaneum*. In locations where the vegetation is abundant and the soil fertile and where the layer of "terra rossa" has increased in depth by the disintegration of the rock, *Triticum dicoccum dicoccoides* is not found, except in the shelter of clumps of bushes and small trees, such as *Poterium spinosum*, *Cistus villosus*, *Zizyphus spina-christi*, *Echinops viscosus*, *Centaurea* sp., etc. This was observed to be the case at Mount Hermon (see Pl. V, fig. 1), at Rosh Pinar (see Pl. I, fig. 2), and in the country of Gilead (see Pl. V, fig. 2).

As to the geological age of the rocks, I have found *Triticum dicoccum dicoccoides* on the Jurassic limestones and dolomites, on the so-called sandstones of Nubia, on the more or less dolomitic limestones of the Cenomanian and Turonian, and on the lower Eocene limestones, as well as on the basalts and basaltites. The only formations on which it does not thrive seem to be the Senonian rocks (made up chiefly of chalky and soft limestones or of flints) and the Nari, a conglomerate generally formed of elements of Senonian origin and similar to the "caliche" of the southwestern United States. This was observed at Gilead, as well as in the neighborhood of Rosh Pinar. In this latter locality I made sure that *Triticum dicoccum dicoccoides* was not to be found on the Senonian formations, which are there very extensive and varied, being represented by chalky marls, bituminous limestones, and limestones of *Schloenbachia olivetti.*

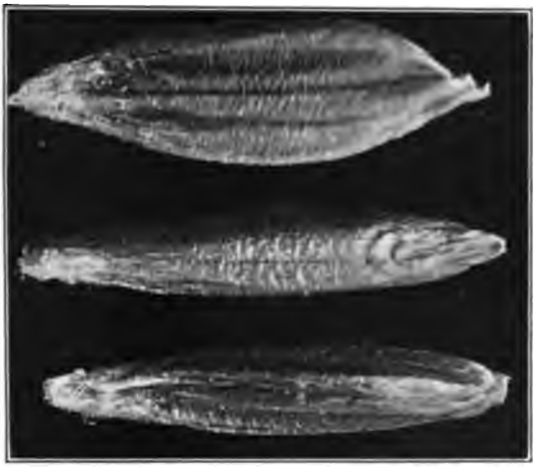

FIG. 1.—GRAINS OF TRITICUM MONOCOCCUM; SIDE, DORSAL, AND VENTRAL VIEWS.

(Enlarged 8 diameters.)

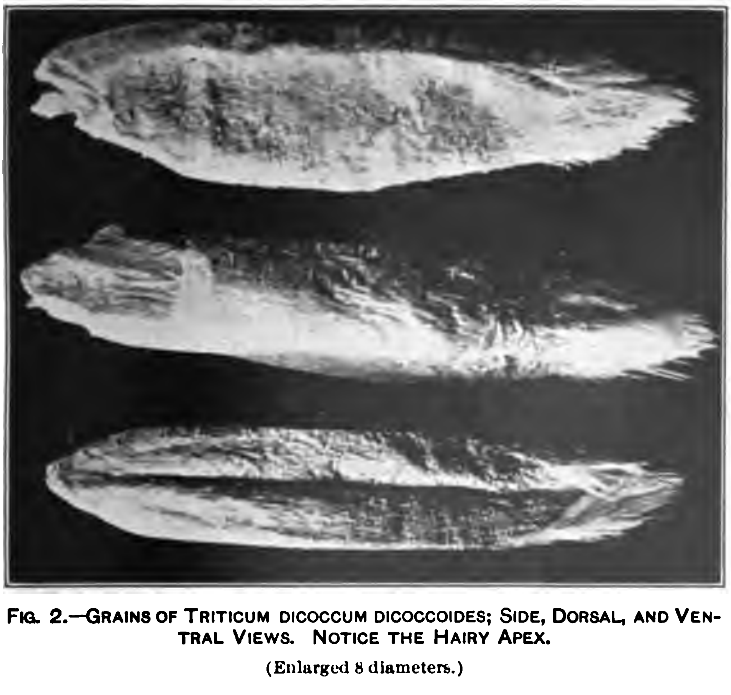

FIG. 2.—GRAINS OF TRITICUM DICOCCUM DICOCCOIDES; SIDE, DORSAL, AND VENTRAL VIEWS. NOTICE THE HAIRY APEX.

(Enlarged 8 diameters.)

We have seen that the wild emmer prefers rocky soils and has not been found up to the present time on the broad plains and vast steppes. Thus, I could not find it at the Ghor (the depression of the valley of the Jordan) either in 1907, when I searched for it in the neighborhood of the Lake of Tiberias, or in 1908 at the mouth of the Jabbok. It disappeared also on the road from Rasheyya to Katana when we reached the Senonian formations and the steppe toward the east. It does not seem even to extend to the edges of the rocky ground, but leaves a sort of protecting belt of rocky land between it and the alluvial, diluvial, or oolithic soils which border it.

Further search ought to be made to find out how far *Triticum icoccum dicoccoides* extends toward the southeast of the country of oab and toward Arabia, as well as how far north along the Lebanon nd the Anti-Lebanon. Moreover, we should look further in the Cis-Jordan region, where it probably extends farther than the terri- ory lying between Rosh Pinar and the northern part of Lake Tiberias.

WHERE DID THE CULTIVATION OF CEREALS ORIGINATE?

I believe that a careful consideration of the foregoing facts will hrow some light on the question of the origin of the cultivation of reals. I shall consider only three of the numerous hypotheses for- ulated in regard to this problem: First, there is the ingenious eory of the Count of Solms-Laubach, set forth in his work "Wei- n und Tulpe," etc., previously cited.

He admits the polyphyletic origin of *Triticum aestivum*, but, hav- g definite proof that wheat was cultivated in Egypt at least four ousand years before the Christian era and at least three thousand ars before the same era in China and assuming that the Egyptian d Chinese civilizations were entirely independent and without in- ence upon one another, he reaches the conclusion that the cultiva- on of *Triticum monococcum* and of the prototype of *Triticum stivum* must have begun in an age so remote that the division of nd and sea, the climatic conditions, and the resultant flora were ery different from those of the present day. It must, then, have ken place in central Asia, in the neighborhood of the basin of the arim, and at a time when the Desert of Gobi was still covered by e sea of Han-hai. Later, *Triticum monococcum* must have em- rated westward, while the prototypes of *Triticum aestivum* dis- ppeared and only their cultivated descendants reached the west. ut according to recent research it is not so certain that the Egyp- n civilizations were entirely independent, and we hesitate to cept a theory which is doubtful in its conclusions, even though sed on irrefutable geological premises.

Körnicke, as well as Schweinfurth and Ascherson, has alway thought that the cultivation of wheat originated in western Asia i the region of the Euphrates. A. de Candolle also reached the sam conclusion nearly thirty years ago as a result of his study upon th origin of cultivated plants. We take pleasure in quoting him: "Th Euphrates Valley lying nearly in the middle of the belt of cultiv tion which formerly extended from China to the Canaries, it is e tremely probable that this valley was the principal habitation of th species in very early prehistoric times. The area may have extende toward Syria, as the climate is very similar, but to the east and we of western Asia wheat has probably never existed but as a cultivate plant, anterior, it is true, to all known civilization."

The most recent theory—that claiming that the cultivation cereals originated in Europe—has been discussed elsewhere,[a] and hardly seems worth while to bring it up again. No naturalist wi agree with Much, Hoops, and the other supporters of this hypothesi

SUMMARY OF STUDIES OF THE WILD CEREALS.

I may say as a summary of the result of my investigations—

(1) I have fully confirmed the opinion of Körnicke, who was th first to assert that the specimen collected by Kotschy was a wi emmer, named by him *Triticum vulgare* [*dicoccum*] *dicoccoid* This Triticum is a native of southern Syria and is the prototype our cultivated wheats, or at least one of the oldest forms deriv from such a prototype.

(2) I have shown that *Triticum monococcum aegilipoides*, as we as *Secale montanum*, is indigenous to the region of Mount He mon and that rye (*Secale cereale*) occurs in the Orient, where it w thought to be entirely unknown.

(3) I have found forms morphologically intermediate betwe *Triticum dicoccum dicoccoides* and *T. monococcum aegilipoid* Experiments in crossing, which are to be made later, will sho whether these forms are only morphologically intermediate whether they have closer sexual affinities than those which ex between the cultivated forms of *Triticum dicoccum* and *T. mon coccum*.

(4) I have collected certain forms of *Triticum dicoccum dicocco des* in which the development of the glumes and the whole appea ance of the head recall *Triticum polonicum*.

(5) We have seen that *Hordeum spontaneum* is a satellite, so speak, of *Triticum dicoccum dicoccoides*, and that the cultivation the two species may have been begun at the same time.

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[a] Aaronsohn, A. Contribution à l'Histoire des Céréales. Bulletin de Société Botanique de France, March-April, 1909.

(6) I believe that the existence of all of these prototypes—that is to say, of oats, wheat, barley, and rye—in a single region, Syria and Palestine, tends to show that the cultivation of cereals must have originated there, or at least in closely adjoining localities.

ECONOMIC POSSIBILITIES OF WILD EMMER.

Hitherto we have devoted our attention to the theoretical and purely scientific phase of this question, but I have thought from the first that it may have a practical and economic interest. The fact that *Triticum dicoccum dicoccoides* endures the most extreme climatic conditions seems to me to be very important when we consider the future economic possibilities of the plant. Its distribution extends vertically for more than 6,500 feet. I have found it from 325 to 500 feet below the Mediterranean in the vicinity of the Jabbok (eastern tributary of the Jordan) and up to 6,000 to 6,300 feet above sea level at Mount Hermon, in the zone of alpine plants.

By the selection and crossing of this wild cereal, which prefers poor, rocky, shallow, dry soil and thrives without any cultivation, we should be able to produce new races which will be very persistent and very hardy. In this way we can extend the cultivation of wheat to regions where it is at present impossible on account of the low quality of the soil and the severity of the climate.

The writer has had the pleasure of seeing that many eminent scientists and practical men share this opinion. Körnicke's son and Mr. M. A. Carleton, the Cerealist of the Bureau of Plant Industry, are working on this problem. In the Vossische Zeitung for September 3, 1908, Professor Schweinfurth gives an account of the experiments carried on by the late Professor Körnicke, which will be continued by his son and successor in the chair of botany in the Agronomic Institute of Bonn-Poppelsdorff.

Of the thirty-six plats sown the first year of Körnicke's experiments more than thirty produced splendidly developed heads. Professor Schweinfurth shares my belief that this cereal shows very exceptional hardiness and adaptability, and he is certain that by selection and crossing we shall obtain some races especially adapted to arid regions and other races valuable for cold and elevated localities. Out of thirty-six plats sown last year, thirty-five came to fruition, and some of them produced heavier and more beautiful seeds than any of our cultivated wheats.

The countries adjoining the regions where *Triticum dicoccum dicoccoides* has been found should be carefully explored. We should determine its exact area of distribution and thoroughly study its numerous varieties and forms, their life history, pollination, etc. This would place us in a position to utilize these wild varieties to the best advantage in the creation of new cultural races. It is im possible to foresee the importance of the results that may be th obtained. Those who know what is being done at present in t way of creating interesting races by selection and with our prese methods of hybridization will agree with me in saying that the cul vation of wheat may be revolutionized by the utilization of the wild forms.

It seems to me that we are justified in hoping to produce rac better adapted to the semiarid regions of Algeria, Tunis, Syri Egypt, Turkestan, and America. If we secure races that will enab us to increase the yield by as much as 1 bushel per acre on the vast areas, the world's total production of wheat will be very m terially augmented.

The study of the wild types of our cereals should not serve mere botanical and historical ends. It has a practical, an economic— may even say a social—importance. Its ultimate aim is to produce little more bread at a little less expense where production is diffic and costly, and to render this production possible where up to t present time it has been impossible.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 181.

B. T. GALLOWAY, *Chief of Bureau.*

THE CURLY-TOP OF BEETS.

BY

HARRY B. SHAW,

ASSISTANT PATHOLOGIST IN COTTON AND TRUCK DISEASES AND
SUGAR-PLANT INVESTIGATIONS, IN COOPERATION WITH
THE BUREAU OF ENTOMOLOGY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 25, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 181 of the Bureau series a manuscript entitled "The Curly-Top of Beets," by Harry B. Shaw, Assistant Pathologist in Cotton and Truck Diseases and Sugar-Plant Investigations of this Bureau, in cooperation with the Bureau of Entomology.

The sporadic outbreaks of this disease have caused much loss to sugar-beet growers in our Western States during the past ten years. Curly-top has been under investigation by this Bureau since 1902, and Bulletin No. 122 of this Bureau, by Dr. C. O. Townsend, was published in 1908 to show the lack of proof that bacteria, fungi, or unfavorable environmental conditions were the cause of curly-top. Since that date Mr. Shaw has proved that the disease results from the punctures of an insect, a theory previously advanced by Dr. E. D. Ball, then special agent of the Bureau of Entomology. This group of plant diseases, another example of which is stigmonose of carnations, described by Mr. A. F. Woods in Bulletin No. 19 of the Division of Vegetable Physiology and Pathology, is of special interest to the plant pathologist on account of the physiological problems involved, but the practical control of these troubles must be based largely upon studies by the entomologist.

To make this discussion of curly-top more complete and of greater practical value Mr. Shaw has included a description of the beet leaf-hopper and its life history, largely drawn from the work of Dr. E. D. Ball, whose assistance, and that of Dr. F. H. Chittenden, of the Bureau of Entomology, is gratefully acknowledged.

Further knowledge of the most effective means of control is hoped to result from studies planned in cooperation with the Bureau of Entomology.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CURLY-TOP OF BEETS.

INTRODUCTION.

Through various publications the serious nature and general character of the curly-top of beets are fairly well known, either under that name[a] or more locally as "blight," "western blight," or "whiskered beets." These names are descriptive of one or another of the symptoms manifested by the stricken plants. Apparently no kind of beet is immune.

Recent experiments and observations have demonstrated not only the primary cause of this disease, but that it is an even greater menace to the production of beet seed than to the culture of beets for sugar.

SYMPTOMS OF CURLY-TOP.

EXTERNAL SYMPTOMS.

The external symptoms of curly-top are numerous and may be found in all parts of affected plants. Commonly the earliest to appear is an inward curling of the inner leaves from the entire margin toward the midrib. Almost simultaneously a distortion of the veins of the affected leaves may be noted; these become crinkled and knotted on the dorsal surface of the leaf (Pl. I, fig. 1, and Pl. II, fig. 1). As the disease progresses more leaves, and finally the whole plant, become involved; nipple-like protuberances develop on the veins, sometimes to the length of about three-sixteenths of an inch, and the whole leaf becomes tightly curled from either side. The petioles remain much shorter than in the normal plant (fig. 1) and become bowed, with the concavity inward; the crown is generally quite perceptibly wider than in the healthy beet, owing largely to an abnormal growth of small and imperfectly formed leaves outside of and around the original set of leaves; and the leaves and petioles bunch closely together instead of opening out and spreading (Pl. II, fig. 2, and Pl. III, fig. 1).

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[a] "Blight" is used in so many other connections that it is deemed better to avoid its use in this paper; neither is "curly-leaf" considered quite as inclusive as "curly-top," since the latter term includes crown, petioles, leaves, and seed stems. However, it is acknowledged that "curly-top" is not an ideal name, because it fails to include the disturbances found in the root.

The foliage is generally of a dark, dull-green color and quite brittle, though thick and leathery in appearance. In severe cases, especially among young plants, the outer leaves soon become yellow, die, and turn brown; the inner whorls follow, until the entire plant is killed.

The roots throw out dense masses of rootlets from the two spiral grooves; hence the names "hairy-root" and "whiskered beets." (See Pl. II, figs. 1 and 2.) The root itself looks tough and fibrous and in many cases becomes sprangling. When pulled up, masses of soil cling to the hair-like rootlets and are with difficulty shaken off. The growth of every portion of the plant is checked, if not entirely arrested.

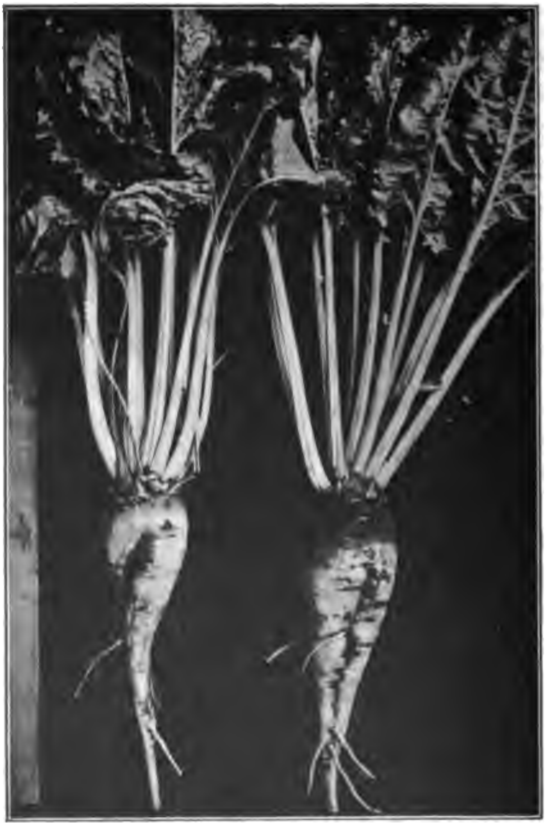

FIG. 1.—Healthy sugar beets, Vilmorin type. (For comparison with beets affected by curly-top.)

In many cases the leaf-curl assumes an alternative form. Instead of an inward curl, the leaf as a whole becomes strongly retracted and each portion between the larger veins is puffed out. This results in a blistered or "savoyed" effect. In this latter type the vein symptoms are not usually so pronounced. Sometimes the two types are combined; the leaf as a whole is then retracted, but the margin curls inward (figs. 2 and 3). Frequently wine-colored stains develop in the form of small circular spots over the surface of leaves of mangelwurzels and garden beets, but no local discoloration has been noted on sugar beets except a faint mottling of young leaves which can only be seen by transmitted light.

INTERNAL SYMPTOMS.

Certain distortions of the cells of the tissues of leaf and stem have been observed in beets affected with curly-top; the fibro-vascular bundles may become darkened throughout the entire length of the root (Pl. III, fig. 2). No decay or softening of the tissues has been noted as a direct consequence of the disease; on the contrary, the root becomes tougher and more fibrous, thus rendering the slicing of the beets more difficult, with frequent clogging of the cutters. In many roots a blackened area, or even a cavity with black walls, may be found in the interior of the crown (27 [a]) (Pl. III, fig. 2); this latter symptom may, however, be found under other conditions (3, 9, 11, 13, 16, 24, 29) and is not considered characteristic of curly-top alone. Very young beets may be so severely attacked that they are killed before the symptoms have time to develop.

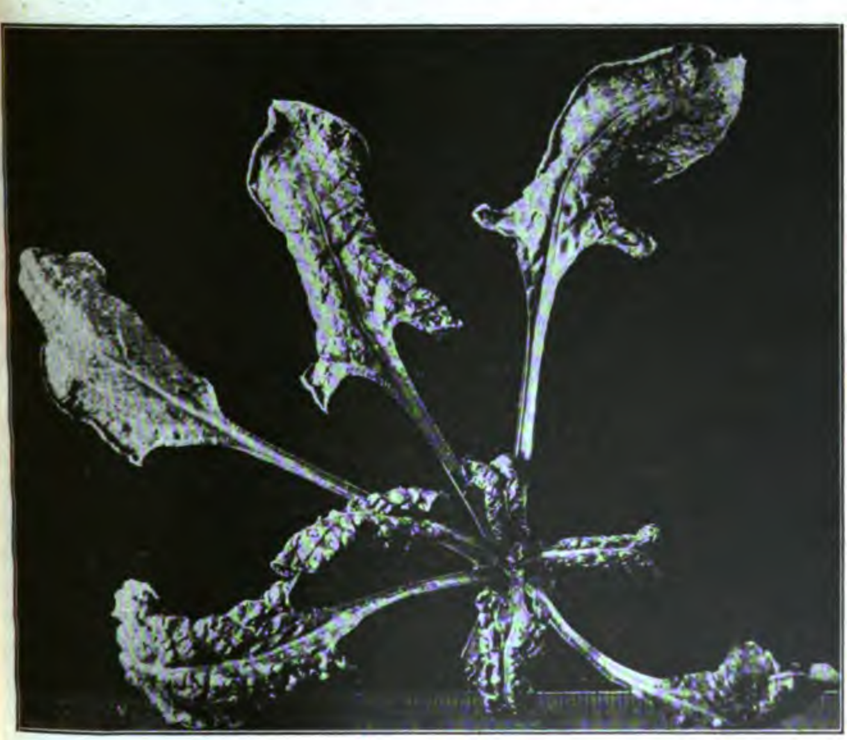

FIG. 2.—Curly-top sugar beet, face of leaves, showing retracted type of curl. Disease produced under test conditions by gradually increasing number of beet leafhoppers until curl developed. Plant at start three and a half months old.

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[a] The serial numbers in parentheses used in this paper refer to the bibliography on pp. 37–40.

SYMPTOMS IN SEED BEETS.

When beets are grown a second season for the production of seed the symptoms of the plants affected with curly-top are similar to those already described, but a much larger proportion of the retracted type prevails. In addition, many seed beets[a] are quite unable to develop seed stems; instead, the leaves gradually wither and the whole plant dies. In other cases feeble stems are produced which may or may not reach the flowering stage and then dry up and die; still others possess enough vitality, though badly dwarfed and stunted, to bear and mature seed (Pl. VI, fig. 1).

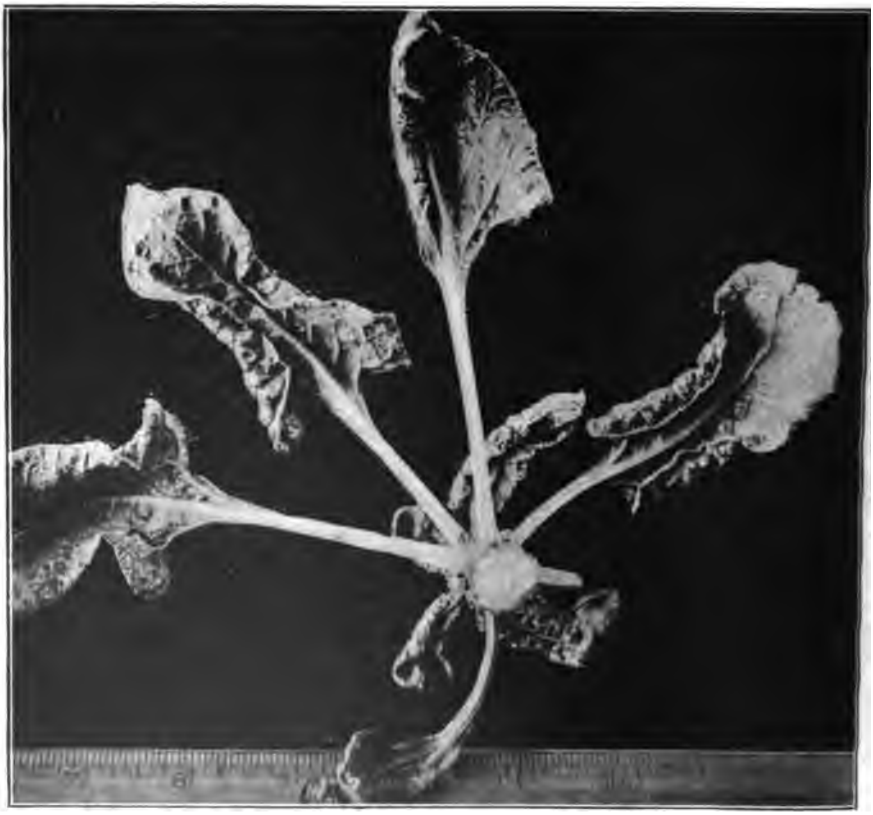

FIG. 3.—Curly-top sugar beet, dorsal surface of leaves; the same plant shown in figure 2.

Quite frequently the roots of seed beets affected with curly-top are found to have rotted areas of varying extent, sometimes involving the greater part of the root (Pl. VIII, fig. 1). This is not to be attributed to curly-top, but is probably brought about by the entrance of various organisms, such as *Phoma betae*, Rhizoctonia, etc. On the other hand, the root may remain sound and crisp, though the top may exhibit every symptom of a severe case of curley-top (Pl. VIII, fig. 2).

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[a] While the term "mother beet" is probably the more familiar one, "seed beet" is considered better, inasmuch as beet flowers contain both male and female organs. The term "mother beet" implies that the flowers of the seed-bearing plant contain only the female organs.

ONLY ONE SYMPTOM REALLY CHARACTERISTIC.

It is to be remarked that most of the symptoms of curly-top, taken individually, may appear under other pathological or physiological conditions; so far as observed, the one real exception is the vein symptoms. However, the totality of the symptoms described in this section has not been observed apart from curly-top.

CAUSE OF THE DISEASE.

THEORIES.

Until quite recently the cause of curly-top was unknown. Numerous theories have been advanced to account for it. Among the more plausible are the following: Bacteria, fungi attacking the leaves, fungi attacking the roots, insects, abnormal moisture supply, abnormal soil conditions, poor seed, and a combination of unfavorable conditions (26, 27).

After wide field observations Dr. E. D. Ball, then special agent of the Bureau of Entomology, stated (4, 5, 6) that in his opinion the disease is caused by the beet leafhopper[a] (*Eutettix tenella* Baker, Pl. I, fig. 1). Prof. E. G. Titus, formerly collaborator of the Bureau of Entomology, while engaged in entomological experiments observed the appearance of curly-top on beets in breeding cages in which some beet leafhoppers were found (6; also footnote, p. 23).

PRELIMINARY EXPERIMENTS.

The writer first turned his attention to the curly-top of beets late in the summer of 1907. Early in June of that year he had noted in the experimental field at Garland, Utah, a few cases of the disease among sugar beets. The earliest of these were among pedigree strains and among garden beets, both of which germinated and grew with much less vigor than the standard varieties of sugar beets. As the season advanced more cases appeared sporadically throughout the field.

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[a] In this paper the beet leafhopper (*Eutettix tenella* Baker) will be referred to simply as the leafhopper.

Among the standard varieties there was apparently little difference in susceptibility. Several species of leafhopper were noted as being generally, though not abundantly, distributed over the field. A small lot of seed was sown in July; quite late in the season some of the seedlings were inclosed in a cheesecloth-covered cage to exclude leafhoppers and other insects.

No curly-top developed among the caged plants; some cases appeared in the open row. This experiment was of little value, because all of the plants had been exposed to insects for some time before any of the plants were isolated. Plans were then made to observe the beets with special reference to this disease from the outset of the following season.

With the beginning of the season of 1908 various experiments were started looking to the solution of this problem. These covered, in a preliminary way, almost all the ground suggested by the theories heretofore mentioned, with negative results so far as curly-top is concerned. The ground being thus cleared, the experiments were focused on the study of the effects of the work of certain sucking insects, notably thrips, red spiders, aphides, and leafhoppers, all of which were numerous in our field at Garland.

It was observed that each of these insects produced characteristic effects on beet leaves. At the outset it was deemed desirable to ascertain the specific effects of the attacks of each kind of insect upon beets. This was desirable not only to determine conclusively whether any of these might produce the curly-top symptoms, but, in case they did not, to know just what the effects of each might be. Since all of these insects abound on beets, it was necessary to be able to discriminate the work of each one from that of the others. Then, in case it was found impracticable entirely to exclude the tiny insects from beets isolated with leafhoppers, it might be easy to distinguish effects that could not have been produced by thrips, red spiders, or aphides. In practice it was possible to exclude all except a very few thrips, which entered the cages through the soil.

ISOLATION CAGES.

The construction of some of these cages will be understood on referring to figures 4 and 5. A foundation frame of $\frac{7}{8}$ by 6 inch lumber was used. This was sunk in the soil about 2 inches to prevent the entrance or egress of insects beneath the cage. Upon this foundation a frame of laths, stout wire, or $\frac{1}{4}$-inch soft iron rods bent into hoops was made (fig. 5). Over the frame was stretched loosely a covering of chiffon or silk veiling; then over that one of Brussels netting (figs. 4 and 5). The chiffon is impenetrable to the insects, but will not withstand the weather; the Brussels net is strong, but will exclude nothing smaller than adult leafhoppers; therefore both materials were used together. These covers were drawn well down the sides of the foundation frames and secured there by tacking laths over their free margins to the sides of the foundation frame. Special care was taken to make the corners tight. To place insects in the cage a lath was temporarily removed

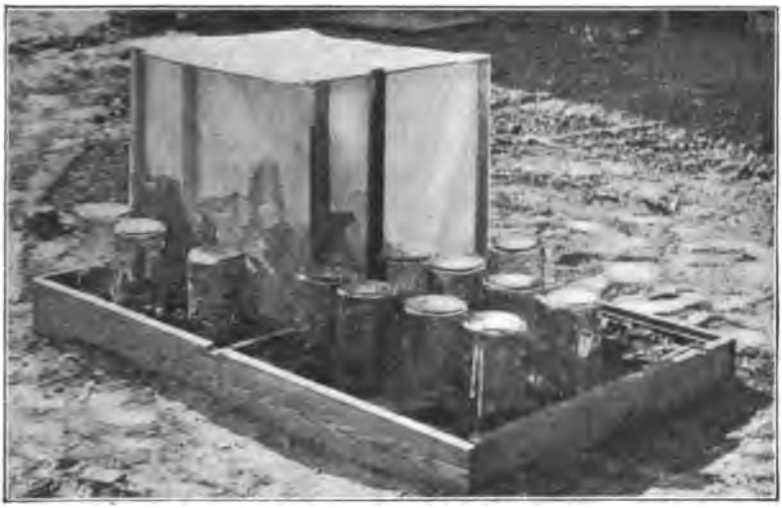

FIG. 4.—Isolation cage and Mason jars for isolating sugar-beet plants.

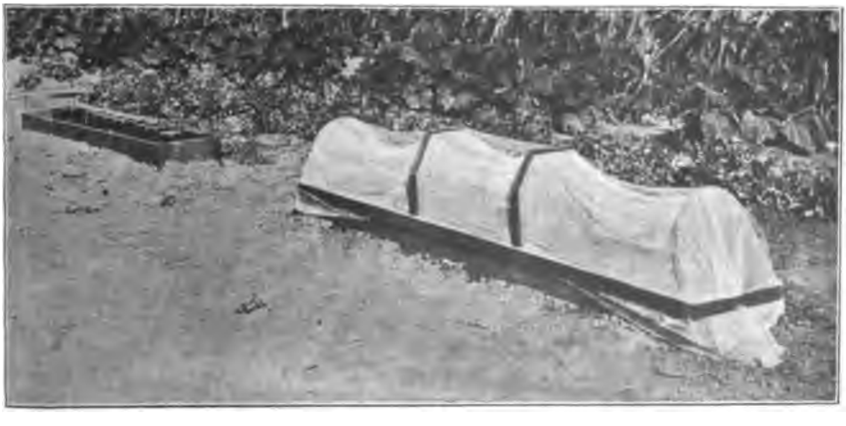

FIG. 5.—Another type of isolation cage.

from one side and the edge of the cover raised. The hoops of iron rod are especially useful for cages, covers, etc., and may readily be made by bending lengths of the rod over the edge of a board that has been cut to the proper size and shape, as shown in figure 6. It will be noted that the sides of this board are convergent. This is done to take up the resilience of the iron rod; otherwise the hoops would straddle too much.

In cages 1 and 2 a standard strain of beet seed was sown on July 18, and more on August 4. This germinated and grew under isolation conditions. Red spiders and aphides were excluded, but a few thrips gained entrance through the soil. Cage 1 was carefully partitioned into three insect-proof chambers. Colonies of thrips were introduced into chamber *a;* into *b* six adult beet leafhoppers were placed, and into *c* red spiders from the beets in the open field. Aphides were placed on beets in cage 3. Cage 2 was reserved as a "control." This was done on August 25; from that time the record of cage 1 is as follows:

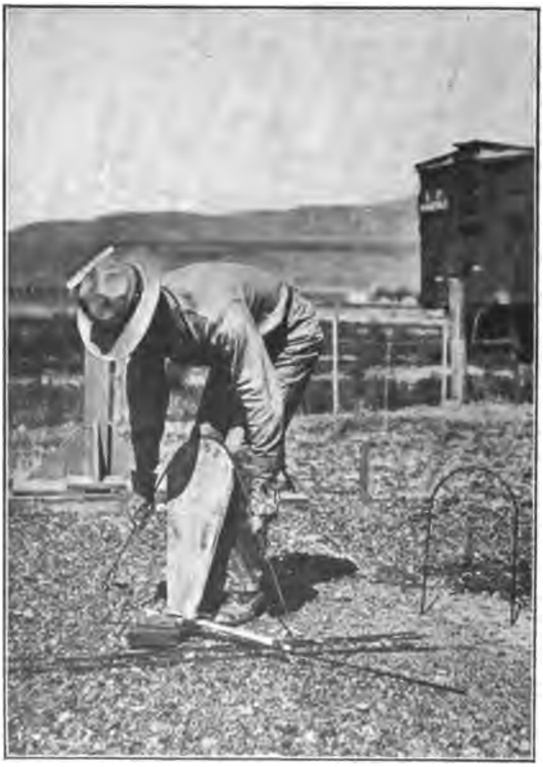

FIG. 6.—A simple method of preparing iron hoops for cages, etc.

August 28. Four more placed in *b.*

September 7. (*a*) Plants made good growth; leaves dark green, many of inner ones badly distorted, some being "savoyed" and some cup shaped by thrips' attacks. (*b*) Scarcely any growth made; leaves dull, leathery, and somewhat blotched or faintly mottled when seen by transmitted light; some leaves strongly concave; no vein symptoms. (*c*) Conditions similar to *a.*

September 8. Placed a few more hoppers in *b.*

September 12. (*b*) Four of the earliest sprouting seedlings show some curl on margin of inner leaves.

September 17. (*b*) Several more hoppers introduced. One leaf completely curled.

September 21. (*b*) Three plants show distinct curly-top symptoms on one or more leaves.

September 28. (*b*) Six plants affected with curly-top.

October 15. (*b*) All plants plainly affected.

None of the control plants became affected with curly-top, nor did any of those in compartments *a* and *c*. Most of the seedlings in this experiment were only about ten days above ground and possessed but two pairs of true leaves when the first hoppers were introduced. The first unmistakable signs of curly-top were noted within thirteen days after the introduction of leafhoppers.

In another frame beet seed had been sown on June 10; this frame was immediately covered with netting to exclude hoppers. Some preliminary experiments, already mentioned, were tried in this frame, but, as stated, with negative results so far as curly-top is concerned. The plants were simply checked in growth. On August 12 this frame was divided in the same way as cage 1. Compartment *a* was used for controls and *b* for the confinement of leafhoppers, and the plants in *c* were individually covered with inverted 2-quart Mason jars as follows: Nos. 1, 2, 3, and 10 with thrips; Nos. 6, 7, and 8 as controls; No. 4 with red spiders and thrips; Nos. 11 and 12 with red spiders; No. 5 with four leafhoppers; and No. 9 with two leafhoppers. At the beginning of this experiment these plants were two months old. The outer leaves were stripped off so that those remaining should not be too crowded under the jars. All the leaves left on the plants were immature, and in them active cell division was in operation. The record for this cage is as follows:

September 1. No. 5, inner leaves curing and vein symptoms showing (Pl. IX, fig. 1); all controls unaffected, except from confinement under glass.

September 4. No. 9, inner leaves curling and vein symptoms appearing; controls still normal.

In eighteen days curly-top symptoms appeared on the growing leaves of plants two months old at the start, with only four and two adult leafhoppers, respectively. Several days after the insects were imprisoned some of them became inoperative because they stuck to the wet walls of the jars. The plants were constantly bathed in moisture during this experiment.

On August 26 a cage was placed over a 2½-month beet. Four leafhoppers were placed in this cage. On August 30, four more hoppers were placed in this cage. On September 6, the inner leaves were curling and vein symptoms appeared. (See Pl. IX, fig. 1.)

Early in September some living beet leafhoppers were sent in mailing tubes to Dr. C. O. Townsend, at Washington, D. C. These were placed on beets in isolation cages in the greenhouse, as follows: September 9, two hoppers; September 16, four more hoppers introduced; October 5, four of the eleven plants now have decidedly curled leaves; October 8, seven plants now affected; October 14, nine plants now affected; October 23, ten affected. The beets grown in the open greenhouse beds remained healthy. The beets were quite young; the hoppers were adults.

In still another experiment in the Garland field some adult leafhoppers were placed in a cage with beets not less than three months old, the outer leaves being first stripped off. In this case the disease was longer in manifesting itself, but when it appeared it took the retracted type (figs. 2 and 3).

NYMPH OF BEET LEAFHOPPER MORE HARMFUL THAN THE ADULT.

During the season of 1909 the writer sent other lots of beet leafhoppers to the Office of Sugar-Plant Investigations, at Washington, D. C., and duplicated these experiments, with similar results.[a] In addition, in order to determine the relative effects of the work of nymphs and adults, some of the former were sent from Idaho and caged with twelve seedling beets, the largest of which was not more than 6 inches in leaf spread. Two days after placing these nymphs in the cage the inner leaves of two beets had begun to curl; in three days three and on the eighth day four plants exhibited symptoms of the disease. At the end of sixteen days but four plants showed curl in a cage in which adult hoppers had been imprisoned. On the fifteenth day all of the plants infested by the nymphs had decided curly-top symptoms. Thus it is shown that the nymphs are more virulent than the adults.

In addition to the varied conditions under which these experiments were made, a further set of conditions was introduced in the field. A portion of two rows of sugar beets was covered with a white muslin awning about 15 inches high. The plants under this awning finally thrust their leaves against it and became badly crowded and the soil remained comparatively wet, yet the disease appeared on these plants in about the same ratio as on those in the open field.

HISTORY OF AN OUTBREAK OF CURLY-TOP IN THE EXPERIMENTAL FIELD AT GARLAND, UTAH.

In the experimental field at Garland, Utah, beet seed was sown on April 14 and the few days following. This is some two weeks later than the average in this locality. In a small plat, separated from the main portion of the field by an irrigating ditch running east and west, were sown several strains of seed from beets grown for several generations in very alkaline soil and known, on that account, to be much less vigorous than standard varieties sown in the main portion of the field. These weakly strains occupied all of the small plat except four rows next to the ditch; the four rows comprised strains of about ordinary vigor. On May 4 a small proportion of these weakly seeds had sprouted; the weather continued cold and dry and the seedlings were much retarded. On May 20 a few beet leafhoppers were noted on this plat. By June 13 all of the beets had been thinned. On June 27 eighteen cases of curly-top had developed among the first few rows farthest from the ditch. The beet leafhoppers appear to have started their invasion on that side, but at this date they had become fairly well distributed over the plat.

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[a] Grateful acknowledgment is made of the valuable assistance of Dr. C. O. Townsend and Misses N. A. Brown and C. O. Jamieson in conducting the cage experiments in the greenhouse at Washington, D. C.

On July 9 ninety-five cases of curly-top had developed; these were mostly confined to the part of the plat where the hoppers started. These insects were now rather abundant.

On July 20 the number of plants showing visible signs was the same as on the 9th. Beet leafhoppers had greatly increased in number and were working over the entire plat. On the side nearest the ditch the beets had become well established and of good size. After this date the symptoms developed very rapidly, until on August 10 there were over three hundred cases.

About mid-October, when the beets were dug, only a small percentage of them was free from signs of the disease. Every plant had then been for some time infested by the insects.

Early in August the leafhoppers had spread over the entire field, but, except for a few cases on the edge of the ditch opposite the badly affected plat, practically no plants in the main field exhibited visible symptoms of curly-top. Few leafhoppers could be found in adjacent fields or in the surrounding district, and cases of curly-top were rare in those fields.

The spring weather was unusually backward, with cold, driving, winds through May and the greater part of June. The sky remained overcast and light showers were frequent during the greater part of this period. Until about mid-May only 0.15 inch of rain had fallen, and the ground had become very dry. During the latter part of May 2.69 inches of rain fell; during June, 3.28 inches. This was distributed in frequent showers of little weight. The strong, cold winds soon dried up this moisture. It was not until July was well advanced that really hot weather set in. During that month but 0.34 inch of rain fell.

EARLY SOWING ADVANTAGEOUS IN PREVENTING CURLY-TOP.

Since it appears that very young beets or those in any way retarded or rendered weakly are more likely to succumb to attacks of leafhoppers, and since well-established beets show a decided resistance to these attacks, it is obvious that anything assisting the establishment of a vigorous and early stand of beets will at least render much less severe the effect of an invasion of the beet leafhopper, should that chance to occur. The plants may even entirely fail to develop curly-top symptoms in the latter contingency, though they will inevitably be checked in growth. However, should these insects be very numerous and no means of speedily destroying or driving them away be devised and put in operation, the beets, however large and vigorous, will finally succumb.

A striking instance of the advantage of early planting is the following: Out of 13 acres of a single field, 10 were sown with beet seed between April 10 and 15, the remaining 3 acres not being sown until between May 10 and 20. Beet leafhoppers were abundant there that season. The beets planted in May became so badly affected with curly-top that only 2½ tons of beets per acre could be harvested. From the 10 acres planted in April, 16 tons per acre were harvested, few of the plants showing curly-top. The same kind of seed was used and the same cultural methods, irrigation, soil, etc., prevailed over the entire field. The disadvantage of late sowing and poor seed is shown in the case recited as occurring in our small plat.

EXTRACTION OF PLANT JUICES NOT SUFFICIENT TO ACCOUNT FOR THE DISEASE.

That the profound disturbances induced in beets affected with curly-top are not alone due to the extraction of plant juices by leafhoppers seems obvious. A plant like the beet is able to withstand the loss of much more juice than could be extracted by the few leafhoppers that are necessary to induce a bad case of curly-top. The writer saw hundreds of such insects as aphides and red spiders on beet leaves, and the only apparent effect was a local leaf-curl, with discoloration of the parts attacked, but no general and persistent disturbance of the plant as a whole, except when the entire plant was almost covered with these insects, in which case the plant was severely checked and each infested leaf curled. But new growth on such a plant is about normal if the insects are removed. The work of but one leafhopper for a few minutes on a young beet has been shown to be capable of inducing the curly-top symptoms. It therefore seems obvious that some active agent is left in the plant tissues which is capable of initiating profound disturbances.

The writer has observed the symptoms only in growing tissue, and not in mature leaves. Apparently all division is strongly inhibited. This inhibition seems to operate unequally, for, though the growth of the leaf as a whole is checked, the vascular bundles seem to be held back more than the parenchyma between the vascular bundles; the latter soon swells out between the larger veins and produces the " savoyed " effect so frequently noted. To the naked eye no puncture is visible, nor is any local discoloration due to the punctures to be seen by reflected light, as may be seen in the case of other species of hopper—for example, *Eutettix strobi* Fitch, which leaves a crimson-lake spot at the site of every puncture. However, on careful inspection the writer has been able to discern a faint mottling of green with lighter green in the parenchyma of the leaves of young beets by transmitted light when the curly-top symptoms were developing.

In some badly infested beet fields in Idaho the writer has observed leafhoppers feeding on the dock (*Rumex crispus* L.), and the leaves, especially the inner ones, of all such docks were thickly besprinkled with small, wine-colored, circular spots. These spots coalesce when very numerous in a small area, and if they appear on the petioles and veins the discoloration runs some distance along the fibro-vascular bundles. As these leaves get older they become suffused with red in the more spotted area (Pl. I, fig. 2). The same phenomenon has also been noted in mangel-wurzels, or stock beets, infested by the leafhopper.

CONDITIONS FAVORING AN OUTBREAK OF CURLY-TOP.

It has been stated by several observers that dry, hot seasons seem favorable to severe outbreaks of curly-top, either because such conditions are favorable to the activity and multiplication of the leafhoppers or because detrimental to an early and rapid growth of the beets, or a combination of both. It appears that a cold, dry, backward spring, when the seed is slow to germinate and makes a still more tardy growth after germination, is particularly favorable to an outbreak of the disease. While it may prove true that hot, dry weather stimulates the activity of the insects and renders the development of the disease more rapid and severe, it does not yet appear to be established that to keep the soil about the beets in a moist condition will prevent the insects from invading them, from multiplying, or from producing the disease. However, some leafhoppers may be drowned during an irrigation, but the reduction in numbers thus brought about is not considered of much avail.

Our experiments during 1908 and 1909 show that leafhoppers are able to work and induce the disease under conditions extremely varied, both as regards temperature and actual and relative humidity. The crucial point seems to be the number of leafhoppers infesting the beets in relation to the size and vigor of the plants. There is little doubt that the weather has an important bearing on the matter, mainly, it is thought, on account of its influence on the growth and consequent resisting power of the beets; also quite possibly on account of its influence on the leafhoppers. Everything considered, there is good reason to urge early sowing of beets in order to get the plants well established before leafhoppers become numerous.

NATURAL AND ARTIFICIAL BARRIERS TO LEAFHOPPER INVASION.

The writer's observations as to the disposition and manner of beet leafhopper invasions lead him to think that certain natural and artificial barriers check or prevent the invasions. For example, the intervention of a considerable area of land occupied by crops not known to act as food plants to the beet leafhopper probably acts as a more or less effective barrier to an invasion, while land immediately contiguous to a wide stretch of sagebrush country is likely to be invaded any season when the hoppers are abundant. It is thought that the intervention of a mountain or a large body of water will act as a barrier and that the direction of the prevailing winds has an influence. Until late in the season of 1909 the writer had not observed the symptoms of curly-top on other plants than beets, but in northwest Idaho he noted numerous leafhoppers on cabbages growing between two badly infested beet fields. The outer leaves of a few of these cabbages exhibited unmistakable vein symptoms and marginal leaf-curl (Pl. IX, fig. 2).

HOST PLANTS OF EUTETTIX TENELLA.

While there is still some doubt as to the original host plants of *Eutettix tenella* Baker, it is rather probable that the principal ones are greasewood (*Sarcobatus* sp.), sea-blite (*Dondea* sp.), *Atriplex* sp., and Russian thistle (4, 5, 6). The writer has found the insect on *Sarcobatus* sp. and *Atriplex* sp. This insect seems to be native to the southwestern part of the United States (4, 6).

DESCRIPTION OF THE BEET LEAFHOPPER.

The beet leafhopper (*Eutettix tenella*) (Pl. I, fig. 1) is very generally, though erroneously, known in the Western States as the "white fly." The white fly, properly so called (*Aleyrodes citri* R. and H.), is a quite different insect and a common pest of citrus trees. The name "white fly" is doubtless somewhat descriptive of the general appearance of the insect, which is of a light yellowish green tint, looking white at a little distance. In size it is almost exactly one-eighth of an inch long and about one-thirtieth of an inch wide. The nymphs vary in size from but little larger than the egg to almost adult size, according to age; their range of color is almost as great as that of their size. More commonly they are of a creamy white, with irregular areas of brown about the abdomen. These brown areas vary greatly in the amount of pigmentation, so that in general appearance the color ranges through pale cream, buff, light reddish brown, and deeper and deeper browns until some seem almost black; a few have distinctly red markings.[a]

Several other species of leafhopper commonly found on beets closely resemble *Eutettix tenella* in size and color, and few but trained entomologists can readily distinguish between them.

The beet leafhopper is single brooded and begins to deposit its tiny white eggs in the stems and midribs of beet leaves from about the end of June—the time doubtless varying somewhat with the locality and local climatic conditions—until the end of August. Probably the majority of the eggs are deposited by the middle of July. The nymphs begin to appear about the second week in July, and the writer has observed their appearance in considerable numbers in Idaho as late as the end of August. Slit-like scars are produced on the beet stems where the eggs have been deposited; sometimes these ovipository scars are very numerous and conspicuous. The egg stage appears to last about fifteen days, and the young insects reach the adult stage in about twenty days more. These adults hibernate and resume their activity the following spring. In Utah and Idaho they have been seen on weeds in May and on beets near the end of May or early in June. The greater portion of the nymph stage appears to be spent among the inner leaves and petioles of the plant, where the egg is hatched, and as the insect approaches the adult stage it gradually works outward.

The beet leafhopper is an exceedingly active insect; its favorite mode of locomotion is by hops of lightning-like rapidity. The range of its leap seems to be about 18 inches. The adult while on beets uses its wings but little. In common with several closely related species it is a true sucking insect; it is provided with powerful head parts and a stout bill. The latter when not in use is tucked snugly against the under side of the body.

The writer is indebted to Dr. E. D. Ball for much of the data in regard to the life history, habitat, host plants, etc., of the leafhopper, and would refer the reader to the works of this writer for many interesting details and technical descriptions (4, 5, and 6).

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[a] A discussion of this species is given in Bulletin 76, Bureau of Entomology, and a brief practical discussion entitled "Preparations for Winter Fumigation for the Citrus White Fly" in Circular 111 of the same Bureau. The latter may be obtained free on application to the Secretary of Agriculture.

BEET GROWERS SHOULD BE ABLE TO RECOGNIZE THE LEAFHOPPER.

It seems highly desirable that beet growers and field superintendents should be able to recognize the beet leafhopper, so that its earliest appearance may be noted. If successful preventive measures shall be devised, it is very essential to be promptly informed of the first appearance of leafhoppers in considerable numbers, so that such devices may at once be put in operation. It has not been shown that any other species of leafhopper is able to induce the curly-top symptoms, though both Doctor Ball and the writer have independently experimented with other species commonly found on beets.

SERIOUS NATURE OF CURLY-TOP.

The serious nature of curly-top may be understood when it is known that in some localities practically the entire sugar-beet crop has been destroyed. The writer has seen fields of beets completely denuded by it. Furthermore, beets that do produce a root of fair size because attacked comparatively late in the season possess a high percentage of impurities and are on that account not so desirable to the sugar companies.

It may be said that beets once affected with curly-top never recover. Even when the affected foliage is cut back repeatedly at intervals of several weeks, the new growth exhibits unabated symptoms (29).

A CONSIDERATION OF CURLY-TOP IN SEED BEETS.

It has been observed by those who have raised beet seed in the regions subject to the scourge of curly-top that a variable percentage of seed beets will manifest symptoms of the disease with the first shoots to appear in the early spring. This has been noted by several members of the Office of Sugar-Plant Investigations and by Doctor Ball (6).

The following specific cases are good illustrations: In addition to the cases of curly-top observed in June, 1907, among sugar beets (see p. 13), the writer noted a fair percentage of seed beets thus affected, but at that time little special attention was given the latter. It was merely assumed that they might have contracted the disease at the same time and in the same manner as the sugar beets, however that might have been. No sugar beets exhibiting visible signs of the trouble were selected for siloing in the fall of 1907. Among those selected for use as seed beets were some of the pedigree and garden beets referred to as showing a large percentage of curly-top, together with a considerable number of apparently healthy beets of standard varieties.

The silos were opened April 10, 1908, and the beets were planted April 10, 11, and 13 in the experimental field at Garland, Utah. Within ten days they began to sprout. In the meantime the weather was very severe, with great extremes of temperature. On May 24 most of these beets had sprouted, and many of the pedigree beets showed suspicious signs of curly-top. The closest scrutiny failed to reveal the presence of leafhoppers at this time. On May 14 a canvass of the entire plat of seed beets showed the trouble to be more widespread than at first supposed, though even at this date no leafhoppers had been seen. By May 20 one portion of the pedigree beets showed signs of the disease to the extent of 48.67 per cent, and another portion 29.36 per cent, as against 3.87 per cent among the standard varieties. At this time a few beet leafhoppers had appeared on the small plat that later became so badly affected. On June 8 the percentage of plants visibly affected was 52.21, 58.54, and 17.19, respectively. The writer could not assign the cause of the outbreak among the seed beets to the few leafhoppers then in evidence. Indeed, the first cases of curly-top did not appear among seedling sugar beets in the plat mentioned until about three weeks later, when the insects had become much more numerous.

The experiments hitherto described in connection with the work of the beet leafhopper on sugar beets, whereby this insect was shown to be the primary causative agent of curly-top, together with the observations just set forth, led to the conclusion that the disease may be initiated in the seed beets by the hopper during the season preceding their use for seed production. In order to determine this point conclusively it was arranged to take advantage of the outbreak of curly-top in the small plat during 1908. To this end there were selected from this plat about one hundred beets of good size and shape that at the end of the season exhibited no visible signs of the disease; also, one hundred similar beets showing well-developed symptoms of the trouble were selected from the same plat. All were carefully siloed for planting in the spring of 1909. Many beets were also siloed from the major portion of the field, where but few cases of the trouble had appeared, though these latter plants had been infested by leafhoppers during the later part of the season.

Very early in April, 1909, these beets were planted out in the usual manner. From the moment of planting, close watch was kept for leafhoppers of any species. Almost with the first appearance of the shoots of the seed beets from the affected plat of last season, whether or not the beets had then exhibited symptoms of curly-top, the characteristic curl and vein symptoms appeared. On May 24 all those beets showing curly-top when harvested at the end of the preceding season had again developed the symptoms. Of those showing no symptoms when harvested, 83 per cent were affected on the same date. Later in the season but 2 per cent of this latter batch was free from visible symptoms of the disease, and even the 2 per cent was checked in growth. Of the large number of beets siloed from the major portion of the field, where practically no cases of the disease had appeared during the preceding season and which were planted out at the same time in the spring for seed production, about 10 per cent had developed curly-top on May 24. It will be remembered that no leafhoppers appeared until May 20, and then but few.

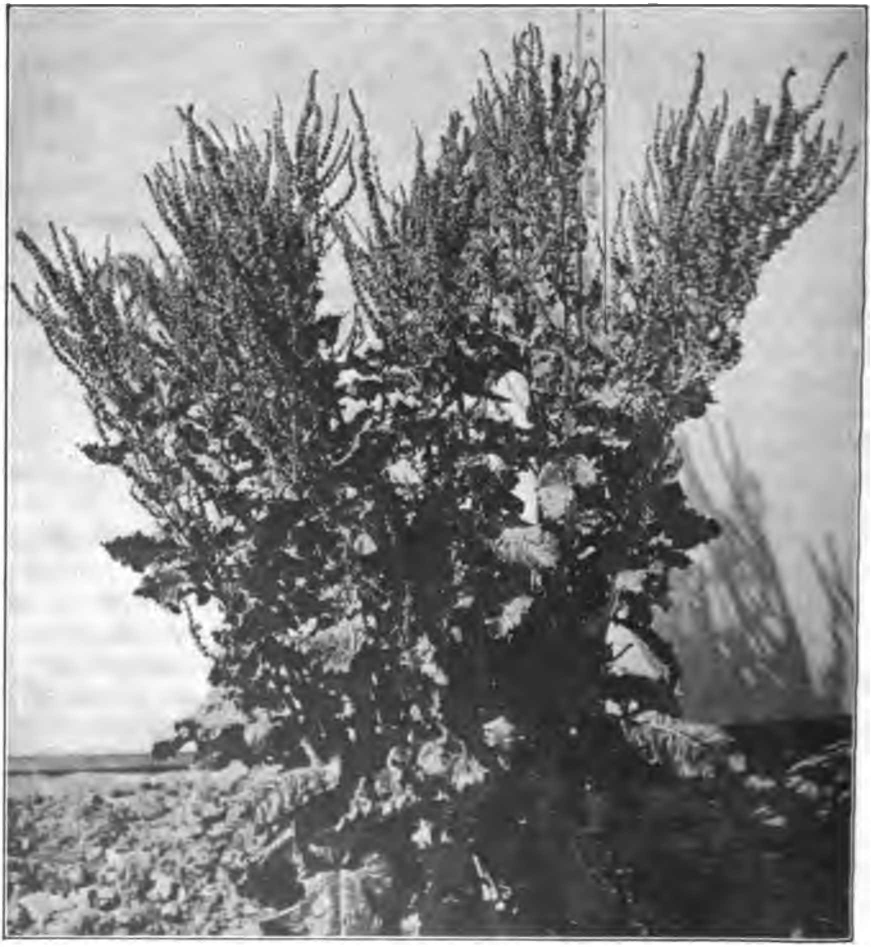

FIG. 7.—Mature healthy seed beet. (For comparison with seed beets affected with curly-top.)

The same spring some of the standard varieties of seed beets (see fig. 7) were planted at Central Farm, about 6 miles from our experimental field at Garland; other lots were planted at North Farm, about 1½ miles away; at Corinne, about 16 miles away, and at Lehi, about 100 miles distant. At these places it was difficult to find a single beet leafhopper during the entire season. Nevertheless, a like percentage of curly-top appeared among the beets planted at each place. Furthermore, there had been planted at Corinne some of the apparently healthy beets from the badly affected plat at Garland. All these manifested the characteristic signs of the disease very early. Numerous seed beets were sent from Fairfield, Wash., and planted at Central Farm in the plat with those just referred to. Among these no curly-top appeared. No beet leafhoppers could be discovered at Fairfield the preceding season.

During the same spring some beets were sent from Garland to Compton, Cal., to be planted there as seed beets. Most of these developed curly-top, although no leafhoppers could be found at Compton. None of the factory beets or seed beets grown there became affected.

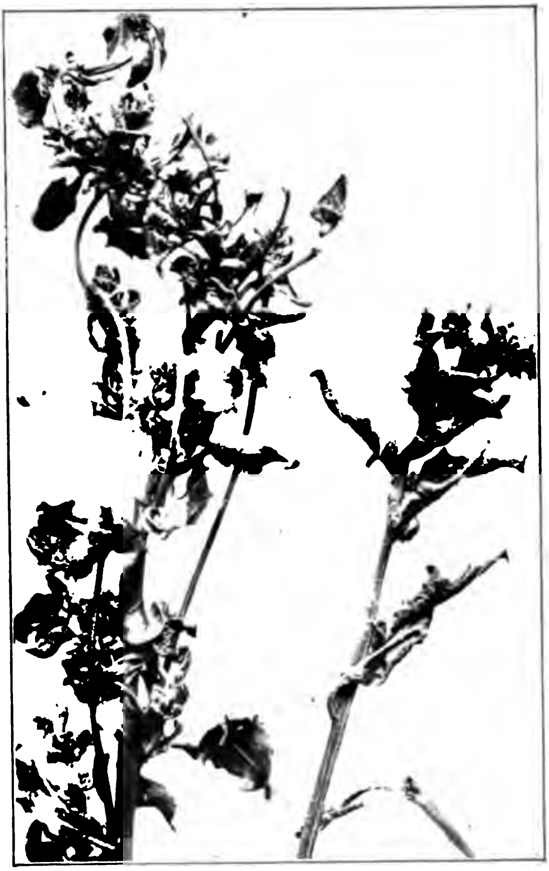

FIG. 8.—Sugar-beet seed stems showing curly-top symptoms. These stems had been denuded of all but single-germ seeds and a few bracts; the new growth alone exhibited curly-top symptoms.

These results go to show that the changes set up by beet leafhoppers are profound and persistent and that while a beet may have been resistant during its first season to the extent of growing to about normal size without exhibiting signs of the disease, some reaction has been initiated that will show itself in the manner characteristic of curly-top the following spring if the beet is planted for seed purposes.

Of seed beets the writer could never observe that plants as a whole ever succumb to the attacks of the leafhoppers during the season they are planted as seed beets. They are too vigorous and resistant, and nearly all the leaves are full grown before beet leafhoppers appear in number. However, individual shoots and racemes put forth late in the season may manifest the symptoms if attacked by leafhoppers (fig. 8). Then, too, the entire aftergrowth, which generally develops late in the summer, after the seed has been harvested, may exhibit pronounced signs of the disease. This actually occurred on the plat at Garland after the seed harvest of 1908, when the aftergrowth of nearly every seed beet became thus affected. This aftergrowth consisted of actively growing and immature leaves in which cell division was taking place.

The symptoms are generally more diverse in seed beets. Apparently the element of greater resistance on account of greater size and vigor is a factor tending to the production of symptoms not commonly noted in young sugar beets. However, these additional, and among sugar beets less usual, symptoms may be seen in sugar beets when quite large plants are attacked by so many leafhoppers that even they finally succumb. These symptoms are those mentioned as the retracted type.

The writer has been able to produce the retracted curl under test conditions by imprisoning a gradually increasing number of leafhoppers with beets that would ordinarily fail to develop the symptoms on account of their size when attacked by the insects (see figs. 2 and 3).

SEVERAL TYPES OF LEAF-CURL ON SEED AND SUGAR BEETS.

As a result of observations on the development of the disease in seed beets the writer has been able to note several types of symptoms on them, as follows:

(1) The type most commonly noted on sugar beets and hitherto regarded as the characteristic appearance of beets affected with curly-top, viz, with leaves strongly curled inward from the entire margin toward the midrib; strongly knotted veins; thickened parenchyma, which in advanced stages is quite brittle, though tough and leathery in appearance; very dark and dull green foliage with outer whorls sear and dead; pronounced inhibition of growth; early appearance of feeble seed stem, which sometimes does and sometimes does not mature seed. (See Pl. I, fig. 1; Pl. II, fig. 1; Pl. IV, fig. 1; Pl. VI, fig. 1; and Pl. IX, fig. 1.)

(2) The type with short, ovate, retracted leaves and short, bowed petioles; tissue between larger veins puffed out as though the parenchyma had outgrown the fibro-vascular tissue; veins generally rather less knotted than in the preceding type; generally the early appearance of abortive seed stems; almost entire inhibition of growth after first month. This type is perhaps the most abundant one among seed beets and is found also on sugar beets that succumb late in the season after attaining a considerable size. (See Pl. III, fig. 1, and Pl. V, fig. 1.)

(3) The type with long, narrow, sinuous, thick, leathery-looking leaves; without marginal curl or vein symptoms; no seed stems; almost entire inhibition of growth after first month or six weeks; dull, dark-green foliage, inclined to russet. (See Pl. IV, fig. 2.) Noted only on seed beets.

(4) The type with small rosettes of leaves similar to those of the second type mentioned, but much smaller; very early cessation of growth; no seed stems; very feeble vitality, yet root apparently quite solid and crisp. (See Pl. V, fig. 2, *B*.)

(5) The type with root apparently as sound and crisp when planted as the most healthy beet, yet making no growth at all.

(6) The type with part of shoots affected with marginal curl, inward; growth not otherwise seriously affected; part of shoots apparently normal.

(7) The type with no visible symptoms of the disease, but general growth checked. (See Pl. VI, fig. 1.)

(8) Combinations of any of the foregoing. (See Pl. V, fig. 2, *A*.)

AFFECTED SEED BEETS ALMOST NONPRODUCTIVE.

The serious nature of curly-top is heightened by the fact that few seed beets affected by it produce seed. Of those possessing sufficient vitality to produce seed stems, many dry up and die before maturity; the very few that produce seed are so puny and stunted as to produce but a small fraction of a normal yield. Thus, it will be seen that, while this species of leafhopper is a serious menace to the sugar-beet crop, it is doubly so when beets are raised for seed. The beets may be quite satisfactory for the manufacture of sugar and appear normal and healthy when harvested, yet have stored within them an active agent that may cut down the seed crop from a few per cent to entire loss.

PERCENTAGE OF LOSS OF SEED BEETS.

When put in plain figures this loss is very striking. To revert to the experiment just mentioned, those plants showing no curly-top when siloed produced an average of only 13.82 grams of seed; those exhibiting signs of the disease when harvested produced but 13.25 grams per plant. The average for the healthy beets was about 375 grams, or about twenty-eight times as much as the yield of affected plants. (See fig. 9.)

During 1905 an important sugar-beet district was afflicted by an invasion of *Eutettix tenella* which resulted in great loss. The sugar company, however, selected and siloed enough apparently healthy beets to plant 4½ acres in the spring of 1906 for seed production. Of these, 1½ acres were entirely unproductive; only 1,200 pounds of seed were obtained from the other 3 acres, or 400 pounds to the acre, or 36.3 grams per plant. In 1906, when the sugar-beet crop was good in the same district and few leafhoppers appeared, enough beets were selected to plant 8.29 acres. These seed beets yielded 16,800 pounds of seed, or 2,038.6 pounds to the acre, or about 177.6 grams per plant. The difference here shown is not so great as in the experiment conducted by the writer because not all of the beets siloed by the sugar company could have been as severely attacked during the preceding season; then, too, the plants used by the writer were set much farther apart than those of the sugar company, thus encouraging a larger yield among the healthy beets.

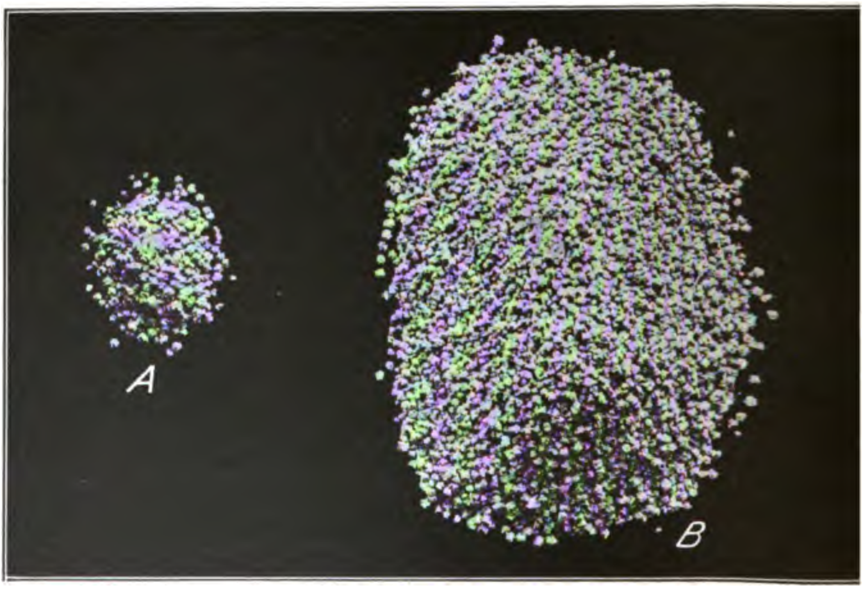

FIG. 9.—Average seed yield of healthy and curly-top sugar beets: (*A*) Average amount from diseased beets, 13.25 grams; (*B*) average from healthy seed beets, 375 grams.

SEVERE OUTBREAKS NOT FREQUENT IN A LOCALITY.

A notable feature of curly-top is that, so far as has been recorded, there never has been a serious outbreak two seasons in succession in any locality. Therefore, the farmer may be encouraged to continue the culture of sugar beets in spite of the heavy loss consequent on a single attack. This opportunity is taken, however, to utter a note of warning to seed producers to the effect that it will be unprofitable to silo sugar beets harvested from an area badly affected with curly-top, even though no beets exhibiting the characteristic symptoms are selected for siloing. Furthermore, should the beet leaf[illegible]oppers be numerous without producing more than a sprinkling of [illegible]nts showing visible signs of the disease, a more or less consider[illegible]le percentage of loss may be expected through the development of [illegible] disease in seed beets the following season. The probable amount [illegible] loss will obviously depend on the number of leafhoppers present [illegible]ring the preceding season, together with the general vigor of the [illegible]nts at that time and the length of time the leafhoppers had been [illegible] work on the beets.

PROGENY OF THE DISEASED SEED BEETS HEALTHY.

Another strange feature of curly-top is that the seed from an [illegible]ected seed beet will produce healthy sugar beets, which in turn [illegible]ord vigorous and healthy seed beets unless in the mean time they [illegible]e attacked by more leafhoppers. Thus it appears that seed from [illegible]ected beets need not be discarded on account of the disease.

GENERAL CHARACTER OF CURLY-TOP.

It would appear from these observations and experiments that the curly-top of beets should be included in the group of plant disturbances known as "stigmonoses," as described by Dr. A. F. Woods in connection with the effects of aphides, thrips, and other sucking insects on the carnation (32, 33, 34, 35, 37), by Dr. N. A. Cobb as occurring on apples, pears, etc. (10), and by Moulton as occurring on the pear (21). Curly-top resembles these stigmonoses in that the disturbances are primarily set up by the punctures of sucking insects—the beet leafhoppers. In certain varieties of beets and in docks punctured by the beet leafhopper, discoloration and spotting of the leaves follow the punctures of these insects, and in young sugar beets a faint mottling of the attacked leaves may be noted by transmitted light (see p. 10); leaf distortions, though differing in character and extent, are common to both. In the case of stigmonose, Woods has shown that when the abnormal changes due to aphis punctures "have once been started in a plant the ill effects continue long after the initial cause has disappeared. If the insects are killed or kept off such a plant the new growth will be free from spots and therefore apparently healthy. It is, however, poor in reserve albumin and has an excessive amount of oxidizing enzyms * * * and is therefore in fact diseased. This malnutrition becomes gradually cumulative from generation to generation of cuttings, and so far as our investigations have gone, can not be cured." In this respect the behavior of curly-top beets is almost identical, the most noteworthy difference being the persistence of the visible symptoms in all new growth of curly-top beets, even after repeated cuttings back of the foliage at intervals of several weeks.

In the cases described by Woods and others the visible effects of the insect punctures are confined to the leaf, or even the portion of the leaf, attacked, whereas, as just stated, the disturbance induced in the curly-top beet affects the whole plant in such a manner that all of the growing foliage shows visible symptoms of the disturbance.

While curly-top is initiated in the same manner as stigmonose and so far as can be discovered (29) can not be attributed to bacteria or fungi, the physiological disturbances seem to bear a close resemblance also to those described by Woods and others (7, 15, 18, 19, 20, 23, 24, 25, 34) as mosaic. In the case of curly-top it is true that the rather conspicuous leaf mottling noted in the mosaic disease is absent, except for the faint mottling already referred to as occurring in leaves of young beets affected by curly-top and visible only by transmitted light. On the other hand, the general nutritional disturbances and the unbalancing of normal enzym activities described by Woods (33) seem to be duplicated in curly-top beets; in the latter, too, there is a similar persistence of visible symptoms. Still another feature is common to both the mosaic disease and curly-top, viz, under both conditions an affected plant will sometimes yield seed, and in each case that seed is capable of producing normal, healthy plants.

The writer has not yet secured conclusive evidence that these symptoms can be induced in beets by the methods practiced by Woods (34) in the case of the mosaic disease. Indeed, it would appear to him difficult to do so, for the reason that the beet root contains so large a reserve of nutrients. Townsend's experiments (29) and some conducted by the writer seem to negative the idea, but further investigations along this line are necessary. However, the writer is of the opinion that there is a striking resemblance in the general behavior of curly-top beets to that of those suffering from the mosaic disease.

This would indicate that curly-top is the most conspicuous and destructive form of stigmonose and, at the same time, one of the most interesting to the pathologist and physiologist on account of the profound disturbances set up, as well as from its apparent relationship to the mosaic disease. Apart from curly-top the writer has noted stigmonoses of the sugar beet which are identical with those described by Woods, Cobb, and Moulton, as well as with others caused by different species of leafhoppers.

SUMMARY.

The curly-top of beets is related causatively to stigmonose; pathologically and physiologically to both stigmonose and the mosaic disease. It manifests itself through numerous external and internal symptoms of diverse character.

The aggregate of these symptoms presents an appearance characteristic of this disease, though taken individually all except the vein symptoms have been noted under other conditions.

Two distinct types of curl are manifested in this disease—the inward and the outward, or retracted.

The symptoms are essentially alike in factory and seed beets. Among seed beets there is a larger proportion of the retracted type.

The beet leafhopper (*Eutettix tenella* Baker) is the primary cause of the trouble; no outbreaks are known to have occurred outside of the native habitat of this insect, viz, the Southwestern States, generally in the vicinity of what is known as "sagebrush country." The plants named as the probable host plants of the beet leafhopper are found where outbreaks of curly-top have occurred. The insect probably migrates from those plants to beets.

One leafhopper is capable of initiating the disturbances in a young beet, and the effect of numerous hoppers on seedlings may be so severe as to kill them in a few days, before the visible symptoms have had time to develop. The younger the beet the more sensitive is it to leafhopper work.

The nymphs of *Eutettix tenella* produce the symptoms of curly-top much more rapidly than do the adult insects.

No other insect and no other species of leafhopper is known to induce the disease herein described.

Though vigorous beets of four months growth or older will offer considerable resistance, any beet will succumb if attacked by numerous beet leafhoppers. Neither is any variety of beet immune.

The symptoms appear only on immature leaves where cell division is still active—never on full-grown leaves. They appear first on the inner leaves just as the latter unfold.

It is considered advisable to plant as early as practicable after danger of late frosts is over, even to take some risks of late frost, in order to get the beets well established and vigorous before leafhoppers are likely to be numerous.

The disease can not be due to loss of plant juices extracted by leafhoppers, but rather to the introduction by those insects of an active agent.

Few or no beets that develop curly-top symptoms ever recover.

Beets may fail to show symptoms of curly-top to the end of the season if attacked by leafhoppers after they have attained considerable size and vigor. Yet the trouble is initiated and transmitted to the root, only to develop with full virulence in the first shoots the following spring if they be planted out for seed production.

The active agent is therefore persistent and sets up disturbances throughout the whole plant.

It is risky to select for seed purposes any beets from fields badly infested with beet leafhoppers, even though no large number of cases of curly-top appear.

It is useless to make selections for seed from fields badly affected with curly-top.

The inward type of curl is generally produced on young beets. The retracted type appears on seed beets and on sugar beets that had attained considerable size and vigor before the symptoms developed.

Until recently curly-top symptoms had been noted on no other plants than beets, but the writer noted the symptoms on cabbage in 1909.

The punctures of the beet leafhopper produce wine-colored stains on the leaves of dock (*Rumex crispus* L.) and on stock beets, but no such discoloration has been observed on sugar beets.

Anything tending to retard or weaken beets renders them less resistant to leafhopper attacks.

The leafhoppers can induce the symptoms of curly-top under extremely varied conditions of moisture, temperature, and atmospheric pressure.

Weather, soil, etc., may influence the severity of the disease indirectly by modifying the vigor of the beets; possibly, also, the leafhoppers are influenced favorably or otherwise by varying weather conditions.

If seed beets are really healthy when planted—that is, if they have not been subjected to the attacks of leafhoppers during their first season's growth—there is little chance that they will succumb to leafhopper attack during their season as seed beets. An attack involving the whole seed beet is perhaps without exception the result of attacks during the preceding season, though no symptoms may then have appeared. Portions of the later shoots and the aftergrowth of leaves following the seed harvest have frequently been known to develop the symptoms.

Few affected seed beets are capable of producing seed, and then only in very small quantity. The seed yielded by affected seed beets will, however, produce healthy sugar beets, which, in turn, unless in the mean time attacked by more leafhoppers, are capable of becoming good seed beets.

It has not been found possible to communicate the disease from an affected plant to a healthy one.

CONCLUSION.

In cooperation with the Bureau of Entomology, the writer has already carried on some spray experiments in the hope of devising a method of holding the destructive beet leafhoppers in check. It was found that, if it can be thoroughly applied to the insects, a strong kerosene and whaleoil-soap emulsion will kill them. However, the time is so short when the spray might efficaciously be applied that it is not yet certain that spraying will be practicable. Then, too, it is not easy to apply a spray to the beet leafhopper, because its wings thoroughly protect its body and thus prevent the emulsion becoming effective.

Possibly some form of "hopper-dozer" used at the right time will prove more serviceable. More experimental work is needed along these lines.

At the suggestion of the Bureau of Entomology, the following recommendations, found in Bulletin 66, Part IV, of that Bureau, pages 47–48, are quoted:

> More should be known about the places of hibernation and early spring history of this insect. It could not be found in the rubbish around the fields in early spring, and only a few specimens were found in waste places up to the time they appeared on the beets. When once the place where the greater number of them pass the winter is discovered, it may be possible to destroy them there or on their spring food plants before they migrate to the beets. After they have appeared on the beets it will be necessary to be very prompt in the matter of remedies if the injury is to be prevented. A thorough spraying with kerosene emulsion at a strength of 1 part of the stock solution[a] to 5 parts of water would destroy most of the insects that it hit, and by using a drag in front of the nozzles to turn the leaves over and cause the insects to jump, most of them could be reached. Where the insects were coming in in numbers this spray would need to be followed by a second one ten days later.
>
> Several mechanical devices have been used to catch different leafhoppers, and no doubt several of these could be used against this insect with advantage. The tar pan, or "hopper-dozer," drawn over the beets two or three times in

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[a] For directions regarding the preparation and use of kerosene emulsion see Farmers' Bulletin 127, U. S. Dept. of Agriculture, pp. 20–21, and Circular 80, Bureau of Entomology.

the first few weeks would capture a large number of them. The females, before the eggs are laid, are quite heavy and do not jump or fly as readily as the males and would be easily caught. A modified form of this machine, consisting of a couple of tarred wings to be drawn along on each side of a row of beets, while a drag agitated the tops and caused the insects to fly, would probably capture more than the simpler tar pan.

If the insects appeared while the beets were quite small, they could be largely destroyed by rolling when the weather was cold or damp and the insects sluggish.

A number of preventive measures may be used to assist the beets in withstanding the attack of the leafhoppers. In some sections early planting will produce beets large enough to shade the ground by the time the beet leafhoppers appear, and thus reduce the temperature below the danger line. In a few places, like the Grand Junction district in Colorado and Sevier County in Utah, early planting alone would not avail, as the insects appear soon after the earliest beets come through the ground. For such sections early and frequent irrigations would assist in keeping the ground cool until the beets grew large enough to shade it and thus take care of themselves.

All preventive measures will depend for success upon some method of controlling the temperature in the field so that the ground may not be hot and dry at the time the leafhoppers appear.

RECOMMENDATIONS.

Undoubtedly some of the remedies advised against the hop flea-beetle, an entirely different insect and one which also affects sugar beets, in Bulletin 66, Part VI, of the Bureau of Entomology, pages 83–91, and a supplementary article, Bulletin 82, Part III, on the same species, will be found useful. Particular attention is called to the latter publication, by Mr. W. B. Parker, collaborator of the Bureau of Entomology, as the experiments have been very carefully carried out with the hop flea-beetle, which from its habit of flying quickly and hopping resembles leafhoppers, in that the beetles can be reached in somewhat the same way.

BIBLIOGRAPHY.

A bibliography of curly-top follows:

1. Arthur, J. C. Proceedings, American Association for the Advancement of Science, vol. 38, 1889, p. 280.

   Probably the first account of the disease now known as stigmonose.

2. ——— and Bolley, H. L. Bulletin 59, Purdue University Agricultural Experiment Station, vol. 7, 1896.

   Stigmonose of carnations is described under the name "bacteriosis." The disease is regarded as mainly affecting the leaves.

3. ——— and Golden, Katherine E. A disease of the sugar beet root. Proceedings, Indiana Academy of Science, 1891, p. 92.

   These writers verified an appearance of bacteria in the roots of beets affected with a leaf-curl, producing a "savoyed" appearance in the leaves. They were unable to reproduce the symptoms by inoculating with pure cultures of the bacterium.

4. Ball, E. D. The genus Eutettix. Proceedings, Davenport Academy of Sciences, vol. 12.

   Ball here describes various species of leafhoppers, including the beet leafhopper (*Eutettix tenella* Baker), and from the observed appearance of the latter at the time of outbreaks of curly-top of beets is of the opinion that this insect is the cause of the disease.

5. ——— The beet leafhopper. Sixteenth Annual Report, Utah Agricultural Experiment Station, June, 1905, p. 16.

   Ball here holds that the leafhopper (*Eutettix tenella*) is the cause of curly-top.

6. ——— The leafhoppers of the sugar beet, and their relation to the curly-leaf condition. Bulletin 66, pt. 4, Bureau of Entomology, U. S. Dept. of Agriculture. Jan. 27, 1909.

   Ball here describes the beet leafhopper and closely related species and concludes that *Eutettix tenella* is the cause of curly-top. Not experimentally demonstrated.

7. Beijerinck, M. W. Verhandelingen der Kroninklijke, Akademie van Wetenschappen te Amsterdam. 1898.

   Beijerinck proved the absence of bacteria in cases of the mosaic disease and found that only dividing cells (meristemic) can become diseased. He defines a milder form of the disease as a suffering of the chlorophyll bodies; later on a general disease of entire plasmic contents.

8. Büsgen, M. Der Honigtau. Biologische Studien an Pflanzen und Pflanzenlausen. Bes. Abdr., a. d. Jena Zeitschrift für Naturwissenschaft, vol. 25, N. F., vol. 18.

   Büsgen pointed out that the puncturing apparatus of the aphis does not lacerate the plant cells, but passes between them.

9. Busse, Walter. Bakteriologische Studien über die "Gummosis" der Zuckerruben. Zeitschrift für Pflanzenkrankheiten, vol. 7, 1897, pp. 65–77, 149–155.

   A disease bearing resemblance to curly-top is here referred to as "gummosis."

10. Cobb, N. A. Letters on the diseases of plants, 2d series. Miscellaneous publication No. 666, Dept. of Agriculture, Sydney, New South Wales, 1904, pp. 38–50.

Cobb here describes stigmonoses of apple, pear, and other fruits.

11. Cunningham, Clara A. A bacterial disease of the sugar beet. Botanical Gazette, vol. 28, 1899.

A disease of beets in which a leaf-curl is conspicuous is described, and the writer concludes that it is caused by bacteria in the root. This is not clearly established.

12. Czapek. Berichte der Deutchen Botanischen Gesellschaft, vol. 15, 1897, pp. 516–520.

Czapek demonstrated a relation of oxidizing enzyms to geotropic curvature in root of several genera of plants, which suggests the possibility that there may be such a relation between oxidizing and reducing substances in plants sensitive to certain parasites.

13. Golden, Katherine E. A disease of the sugar beet root. Proceedings, Indiana Academy of Science, 1891, p. 92.

This paper describes the isolation of bacteria from roots of beets affected by a leaf-curl.

14. Huston, H. A. Sugar beets. Bulletin 39, part 2, Purdue University Agricultural Experiment Station, 1892, p. 49.

The abnormal appearance of certain beets prepared for analysis is described.

15. Koning, C. Zeitschrift für Pflanzenkrankheiten, vol. IX, 2, pp. 65–80.

Koning largely confirms the work of Beijerinck and others on mosaic diseases.

16. Kramer, Ernst. Die Bacteriosis der Runkelrube (*Beta vulgaris* L.), eine neue Krankheit derselben. Oesterreisches Landwirtschaftliches Centralblatt, vol. 1, 1891, pt. 2, pp. 30–36, and pt. 3, pp. 40–41.

Kramer refers to a disease bearing some resemblance to curly-top as "bacteriosis."

17. Lapham, M. H., and Heileman, W. H. Field operations of the Bureau of Soils, U. S. Dept. of Agriculture; soil survey of the Lower Salinas Valley, California, 1901, p. 506.

The writers found an acid reaction in the soil of fields where curly-top was noted, while the disease did not occur in this district where the soil is alkaline to litmus.

18. Loew, Oscar. Letter to A. F. Woods, dated December 12, 1902, as follows: "The observation that you made, that oxidase can kill diastase, has been made by my assistant (Suzuki) in the case of mulberry leaves. Diseased leaves have more oxidase than healthy ones and no longer transport starch." See Bulletin of the College of Agriculture, Tokyo Imperial University, vol. 4, no. 4.

19. ——— Physiological studies of Connecticut leaf tobacco. Report 65, U. S. Dept. of Agriculture, pp. 11–25.

20. Mayer, Adolph. Die Landwirtschaftlichen Versuchs-Stationen, vol. 32, 1886.

Mayer was the first to make a careful study of the mosaic disease. He found that it can not be caused by an insufficient supply of mineral constituents in the soil.

21. **Moulton, Dudley.** Pear thrips and its control. Bulletin 80, pt. 4, Bureau of Entomology, U. S. Dept. of Agriculture. 1909.

Moulton describes the work of thrips on pear foliage and fruit, showing that these insects produce a stigmonose.

22. **Ravaz, L.** Progrès agricole et viticole, nos. 21 and 24. 1900.

Ravaz describes a disease of the vine under the name "Le Court-Noue," which shows all the characteristic markings and symptoms of mosaic disease.

23. **Smith, Erwin F.** The bacterial diseases of plants. A critical review of the present state of our knowledge. American Naturalist, vol. 30, 1896, p. 116.

Smith reviews the work of Arthur and Golden and holds that the disease they investigated was curly-top.

24. **Smith, Ralph E.** Report of the plant pathologist to July 1, 1906. Bulletin 184, California Agricultural Experiment Station, pp. 240–241.

The appearance of beets affected with curly-top is here described.

25. **Sturgis, William C.** Twenty-Second Annual Report, Connecticut Agricultural Experiment Station (1898), pp. 252, 253, 1899.

A critical review of the work done on the mosaic disease to that time is presented, together with the writer's own observations and conclusions.

26. ——— Twenty-Third Annual Report, Connecticut Agricultural Experiment Station (1899), vol. 3, 1900, p. 253.

The writer here points out that close, clayey soils are favorable to the development of mosaic disease because unfavorable to the even growth of plants.

27. **Suzuki, U.** Bulletin of the College of Agriculture, Tokyo Imperial University, vol. 4, no. 3, July, 1900.

Suzuki refers to a trouble of mulberry trees in Japan that evidently is related to the mosaic disease.

28. **Townsend, C. O.** Some diseases of the sugar beet, in Progress of the Beet-Sugar Industry in the United States in 1901. Report 72, U. S. Dept. of Agriculture, pp. 93–95.

Townsend concludes that curly-top is due to a lack of moisture at the taproot.

29. ——— Curly-top, a disease of the sugar beet. Bulletin 122, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

The writer here reviews the work on the nature and cause of curly-top of beets, recites the various theories advanced, and shows that none of them to that date had accounted for it.

30. **Troube, M. J.** La jaunisse de la betterave. La Sucrerie Indigène et Coloniale, vol. 48 (1896), no. 12, pp. 338–340.

Troude describes a disease of beets occurring in France which causes the leaves to become covered with yellow spots; these finally coalesce and the entire leaf becomes pale yellow. The development of this disease, which seems to bear some resemblance to the mosaic disease, appears to be greatly influenced by weather and soil conditions.

31. **Wilhelmj, A.** Eine Eigenartige Rübenkrankheit. Zeitschrift des Vereins der Deutschen Zucker-Industrie, April, 1907.

The writer is of the opinion that curly-top is closely connected with the water supply.

32. WOODS. A. F. Botanical Gazette, September, 1897, and Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten, vol. 3, pt. 2.

Studies on the carnation disease known as "stigmonose" are described. The author was unable to produce with bacteria the same results as those described by Arthur and Bolley.

33. WOODS, A. F. On the relation of oxidizing enzymes to the destruction of chlorophyll. Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten, vol. 5, pt. 2. 1899.

The destruction of chloroplasts may probably be explained by increased oxidation taking place in the cells.

34. ——— Observations on the mosaic disease of tobacco. Bulletin 18, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1902.

Woods describes the mosaic disease of tobacco and shows it to be probable that there is a disturbance of nutrition due to a lack of balance in the relative amounts or activity of enzymes, that the oxidizing enzymes seem to be abnormally active in the diseased cells, and that the mode of operation is to weaken or retard the action of the diastase. The action of the oxidizing enzymes upon the diastase, therefore, retards the production of sugar, and consequently of proteids and reserve nitrogen in general. The conclusion is reached that the disease can not be due to parasites, but must be attributed to a disturbance of the normal physiological activity of the cells in question. Whatever causes the reduction of available nitrogenous reserve food, especially soluble nitrogen, below the requirements of dividing cells may cause this disease in the tissues of certain plants.

35. ——— Stigmonose, a disease of carnations and other pinks. Bulletin 19, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture. 1900.

The disease is described and its cause attributed to aphides, red spiders, thrips, and other sucking insects. It was reproduced under test conditions with these insects. The effects of the insect punctures on the plant cells are described.

36. ——— Science, n. s., vol. 11, no. 262, pp. 17–19.

Important structural differences between the cells of the green areas of mosaic plants and those of the light areas are pointed out.

37. ——— Carnations in health and disease. Florists' Exchange, vol. 13, 1901, pp. 188–189, and American Florist, vol. 16, no. 664, 1901, pp. 990.

This paper contains substantially the matter presented in "Stigmonose, a Disease of Carnations and Other Pinks."

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Work of the beet leafhopper (*Eutettix tenella* Baker). Fig. 1.- Beet leaves affected by curly-top; also a beet leafhopper. (*A*) A beet le with inward curl and pronounced vein symptoms; (*B*, *C*) two small be leaves with retracted type of curl; (*D*) beet leafhopper, adult. Fig. 2.- Dock leaf (*Rumex crispus* L.) spotted by punctures of beet leafhoppe These spots are of dark crimson-lake, punctate but gradually becomin diffuse; on the fibro-vascular bundles they become lanceolate. Natural si

PLATE II. Work of beet leafhopper on seedling beets. Fig. 1.—Healthy an curly-top sugar-beet seedlings and leaves. (*A*) Healthy seedling; (*B* curly-top seedling with well-developed hairy-root, bowed petioles, ve symptoms, and leaf curl; (*C*) front view of an inner leaf from plant *B* showing marginal curl; (*D*) dorsal view of similar leaf, showing vein sym toms. Fig. 2.—Healthy and curly-top sugar beets of medium size. (*A* Curly-top beet with hairy-root, tough and fibrous root, wide crown wit many imperfect leaves sprouting therefrom; (*B*) beet in perfect health.

PLATE III. Effects of leafhopper attacks. Fig. 1.—Large sugar beet affecte late in the season by curly-top. The retracted type of curl appears to b produced by leafhoppers when they attack a large beet in considerab numbers. Fig. 2.—Sections of healthy and curly-top sugar beets, showi the discoloration of fibro-vascular bundles. (*A*) Longitudinal and (*B* oblique sections of a healthy sugar beet, showing the very light, delicate traced fibro-vascular bundles of the root. (*C*, *D*) Similar sections of curly-top beet, showing the dark areas, dark fibro-vascular bundles, an blackened area with incipient cavity near crown; (*E*, *F*) similar sectio of curly-top beet, showing more pronounced blackening of bundles and cavity with black walls near crown.

PLATE IV. Seed beets affected by curly-top. Fig. 1.—Seed beet exhibiting i ward type of curl. Fig. 2.—Seed beet with long, sinuous type of leav due to curly-top; this type never produces a seed stem.

PLATE V. Seed beets affected by curly-top. Fig. 1.—Seed beet showing r tracted type of curl. The greater portion of seed beets thus affected ha this type of leaf-curl. Fig. 2.—(*A*) Seed beet showing both inward and r tracted types of leaf-curl; (*B*) seed beet with rosette of severely retract leaves and no seed stem. With this type of curl no seed stem ever d velops.

PLATE VI. Seed stems of curly-top beets. Fig. 1.—Curly-top seed beets matu ing seed. Fig. 2.—Seed beet slightly affected by curly-top; very slig symptoms of the disease are apparent; the trouble is shown principally the checking of growth. Compare with Plate VII, which shows a healt seed beet of the same age photographed to the same scale.

PLATE VII. Healthy seed beet of same age as that shown in Plate VI, figure

PLATE VIII. Root conditions of seed beets affected with curly-top. Fig. 1.- Seed beet badly affected by curly-top and root almost destroyed by r (Probably *Phoma betae* or Rhizoctonia.) Rot not caused by the curly-to Fig. 2.—Seed beet with sound root, though badly affected with curly-to This root was as crisp and sound as when siloed more than seven mont earlier.

PLATE IX. Fig. 1.—Two young sugar beets showing curly-top symptoms und test conditions with leafhoppers. These plants were placed under ½-gall Mason jars with two to four leafhoppers, and the disease developed a the result of their attacks. Mason jars shown in the background ov other beets. Fig. 2.—Portion of cabbage leaf showing curly-top sympto after leafhopper attacks; no visible spotting of leaves. These cabbag grew in a small plat between two badly leafhopper-infested fields; ma leafhoppers were noted feeding on the outer leaves of the cabbages.

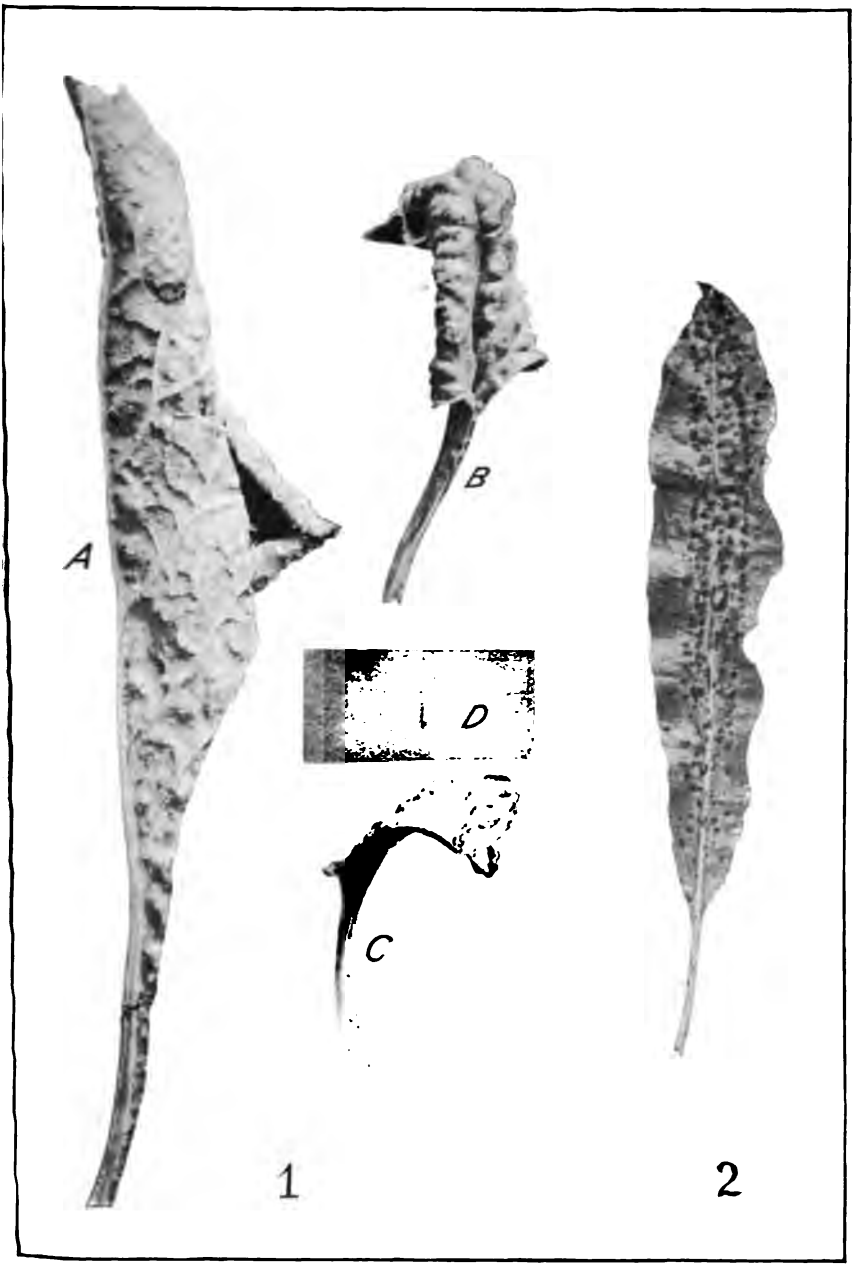

FIG. 1.—BEET LEAVES AFFECTED BY CURLY-TOP (*A*, *B*, *C*); ALSO A BEET LEAFHOPPER (*D*). FIG. 2.—DOCK LEAF SPOTTED BY PUNCTURES OF BEET LEAFHOPPER.

(Natural size.)

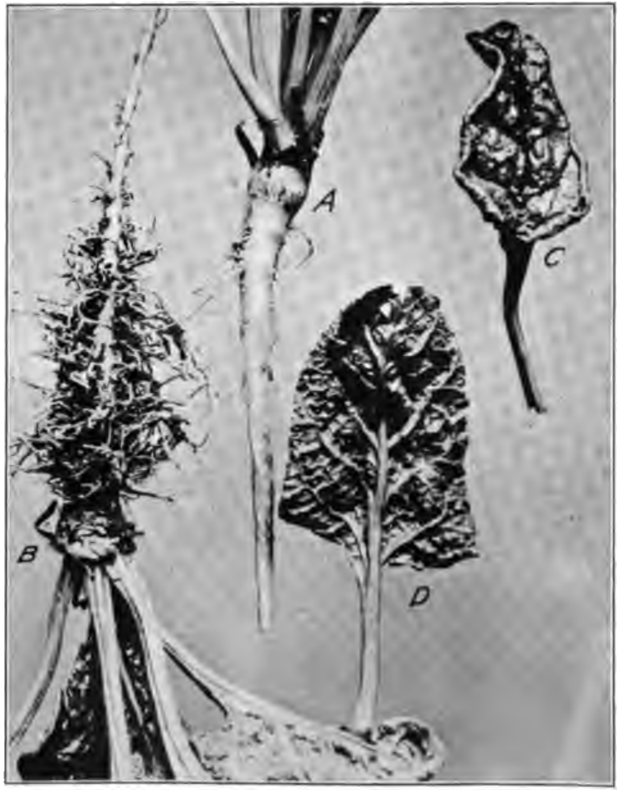

FIG. 1.—SUGAR-BEET SEEDLINGS AND LEAVES IN A HEALTHY CONDITION AND OTHERS AFFECTED BY CURLY-TOP: *A*, HEALTHY SEEDLING; *B*, SEEDLING AFFECTED BY CURLY-TOP; *C*, FACE OF BADLY AFFECTED LEAF; *D*, DORSUM OF SIMILAR LEAF.

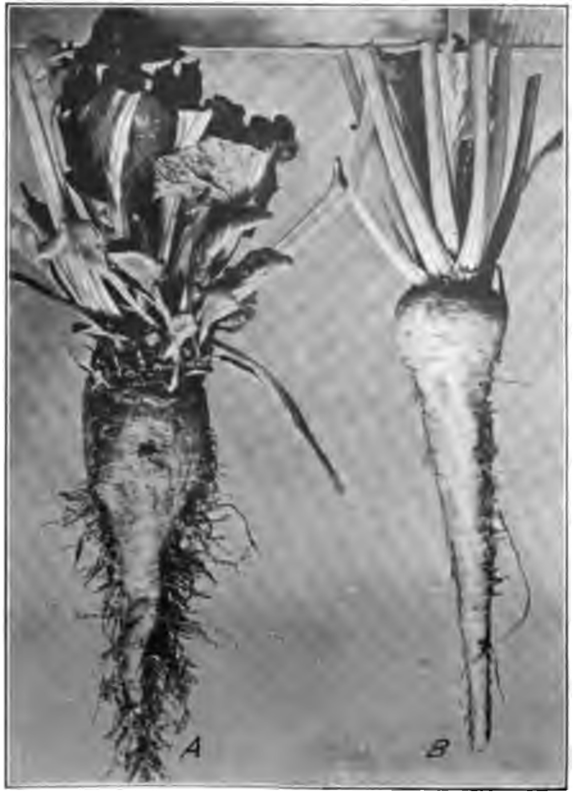

FIG. 2.—HEALTHY AND CURLY-TOP SUGAR BEETS OF MEDIUM SIZE: *A*, CURLY-TOP BEET; *B*, HEALTHY BEET.

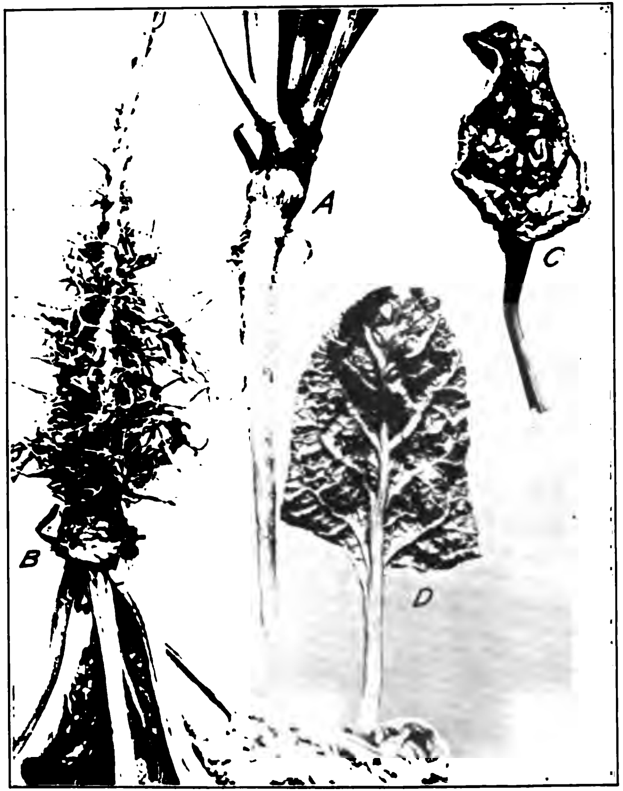

FIG. 1.—SUGAR-BEET SEEDLINGS AND LEAVES IN A HEALTHY CONDITION AND OTHERS AFFECTED BY CURLY-TOP: *A*, HEALTHY SEEDLING; *B*, SEEDLING AFFECTED BY CURLY-TOP; *C*, FACE OF BADLY AFFECTED LEAF; *D*, DORSUM OF SIMILAR LEAF.

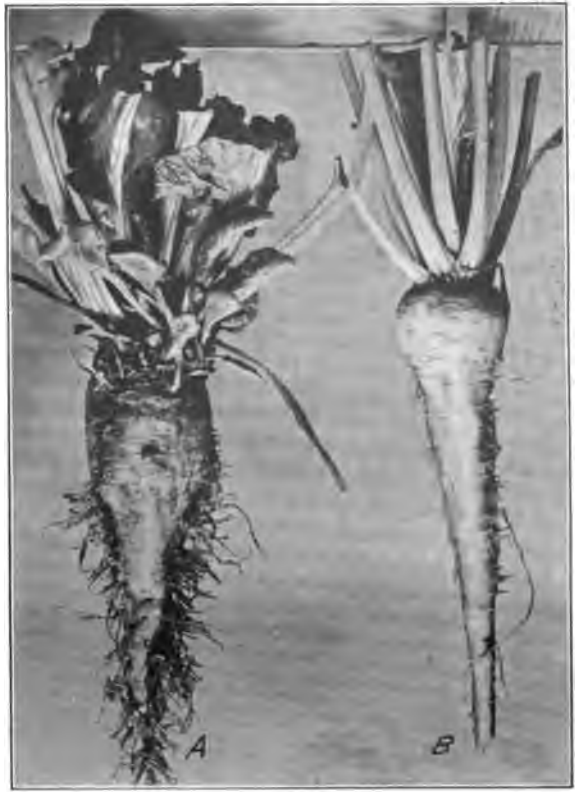

FIG. 2.—HEALTHY AND CURLY-TOP SUGAR BEETS OF MEDIUM SIZE: *A*, CURLY-TOP BEET; *B*, HEALTHY BEET.

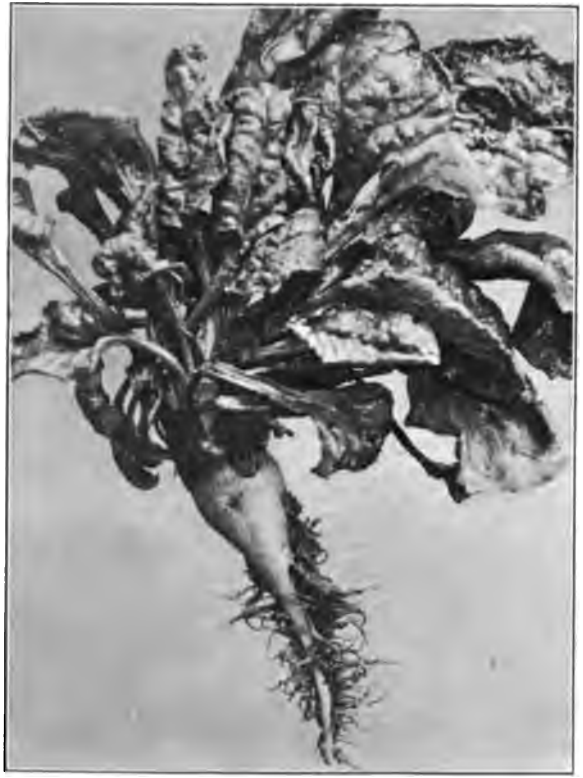

FIG. 1.—LARGE SUGAR BEET AFFECTED LATE IN THE SEASON BY CURLY-TOP.

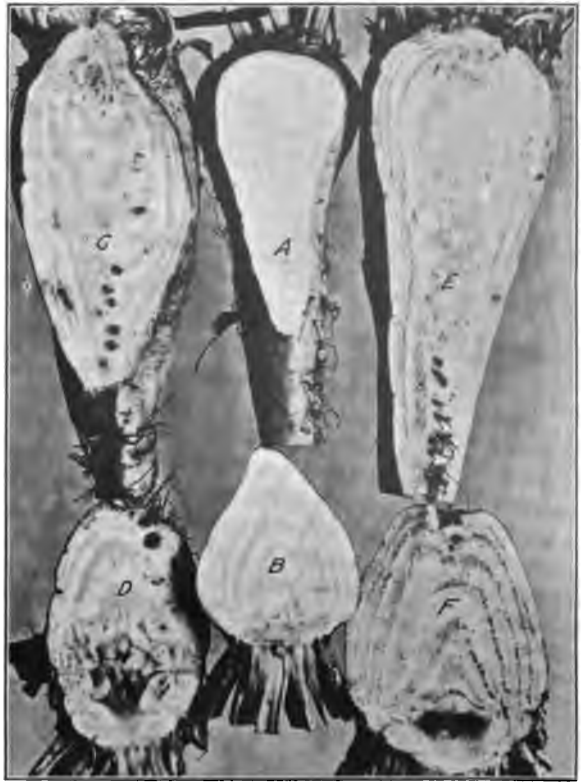

FIG. 2.—SECTIONS OF HEALTHY AND CURLY-TOP SUGAR BEETS, SHOWING THE DISCOLORATION OF FIBRO-VASCULAR BUNDLES.

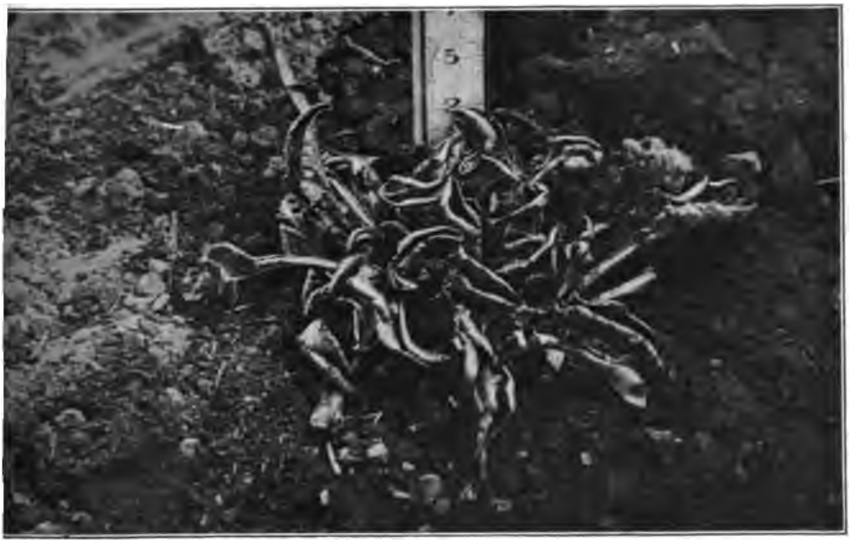

FIG. 1.—SEED BEET EXHIBITING INWARD TYPE OF CURL.

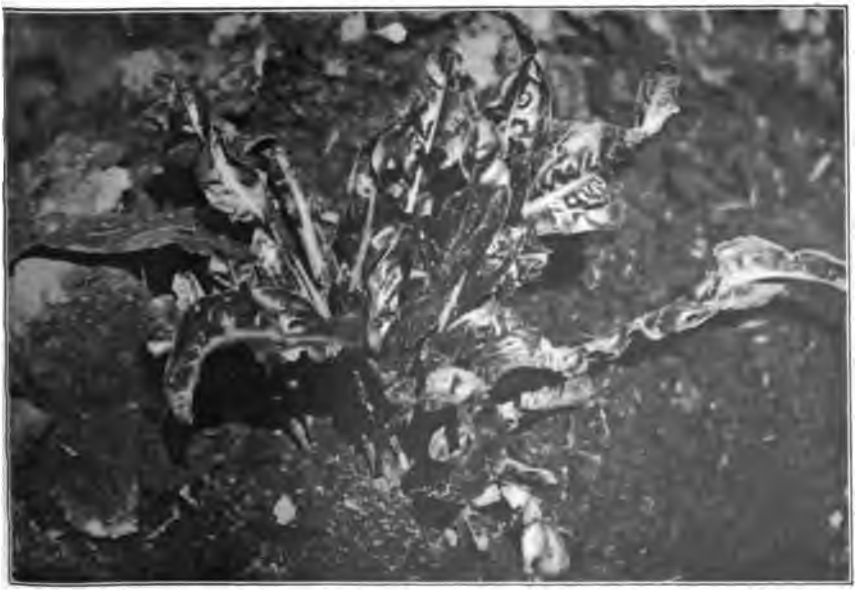

FIG. 2.—SEED BEET WITH LONG, SINUOUS TYPE OF LEAVES CAUSED BY CURLY-TOP.

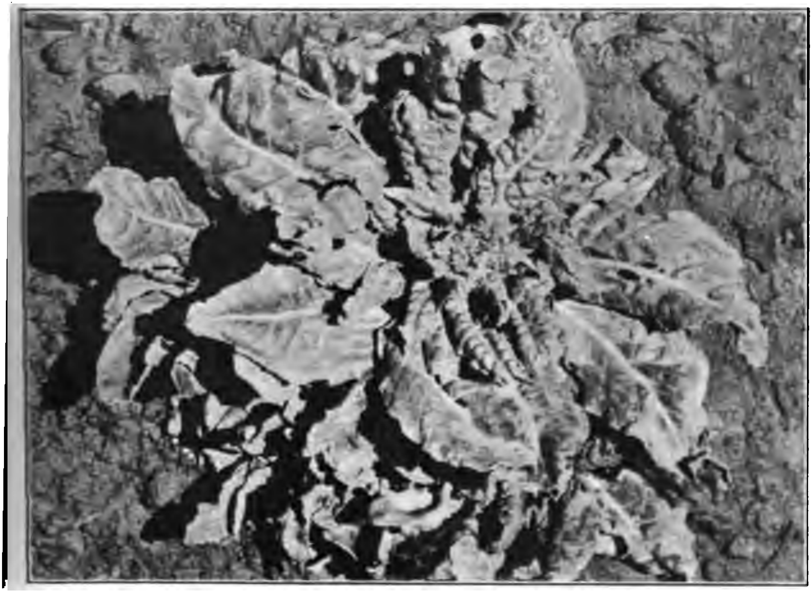

FIG. 1.—SEED BEET SHOWING RETRACTED TYPE OF CURL.

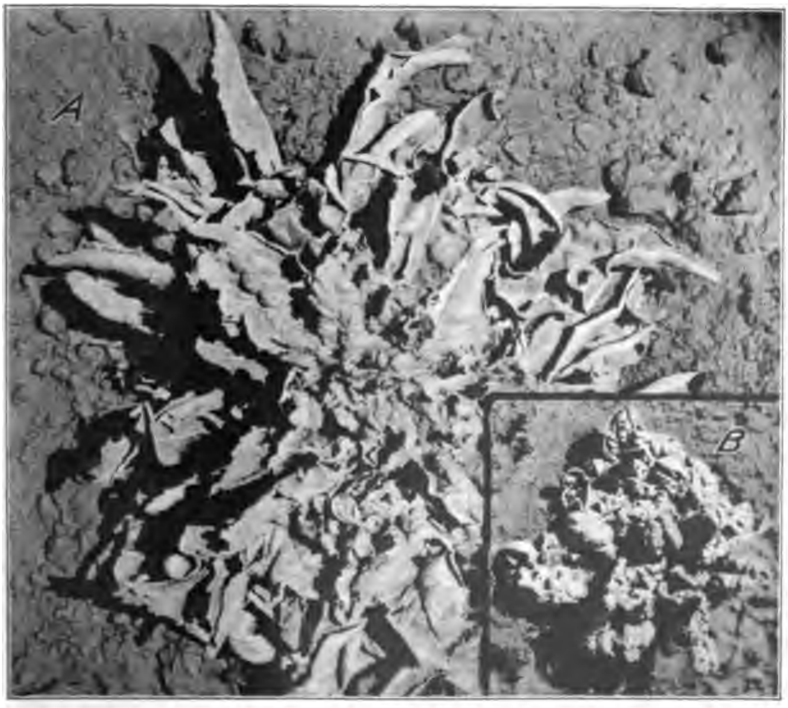

FIG. 2.—*A*, SEED BEET SHOWING BOTH INWARD AND RETRACTED TYPE OF LEAF-CURL; *B*, SEED BEET WITH ROSETTE OF SEVERELY RETRACTED LEAVES AND NO SEED STEM.

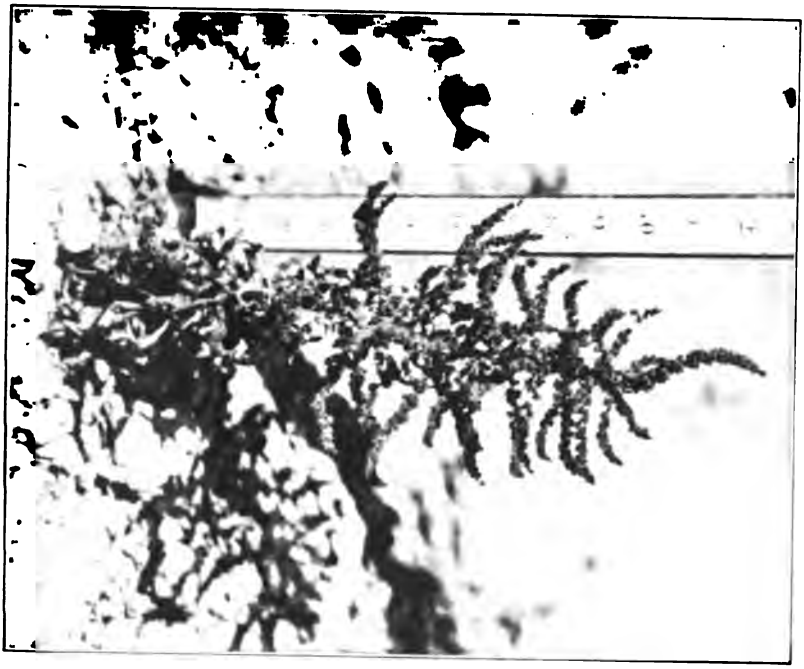

FIG. 1.—CURLY-TOP SEED BEET MATURING SEED.

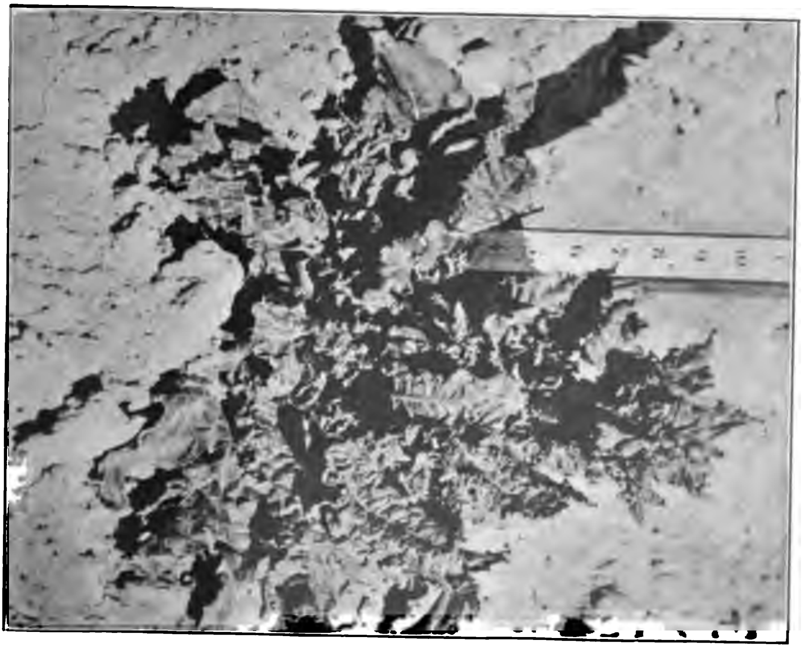

FIG. 2.—SEED BEET SLIGHTLY AFFECTED BY CURLY-TOP.

HEALTHY SEED BEET OF SAME AGE AS THAT SHOWN IN PLATE VI, FIGURE 2.

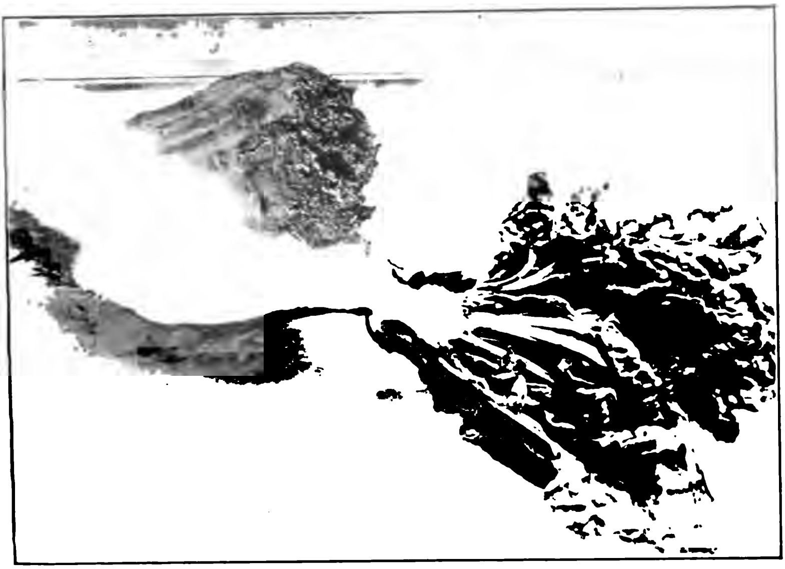

FIG. 1.—SEED BEET BADLY AFFECTED BY CURLY-TOP, AND ROOT ALMOST DESTROYED BY ROT.

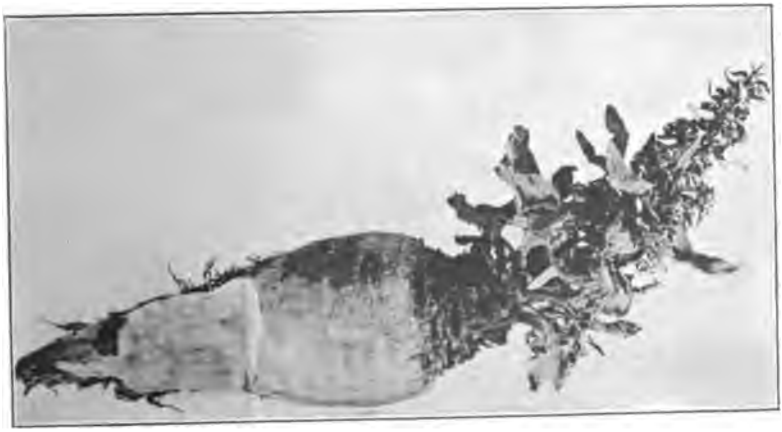

FIG. 2.—SEED BEET WITH SOUND ROOT, THOUGH BADLY AFFECTED BY CURLY-TOP.

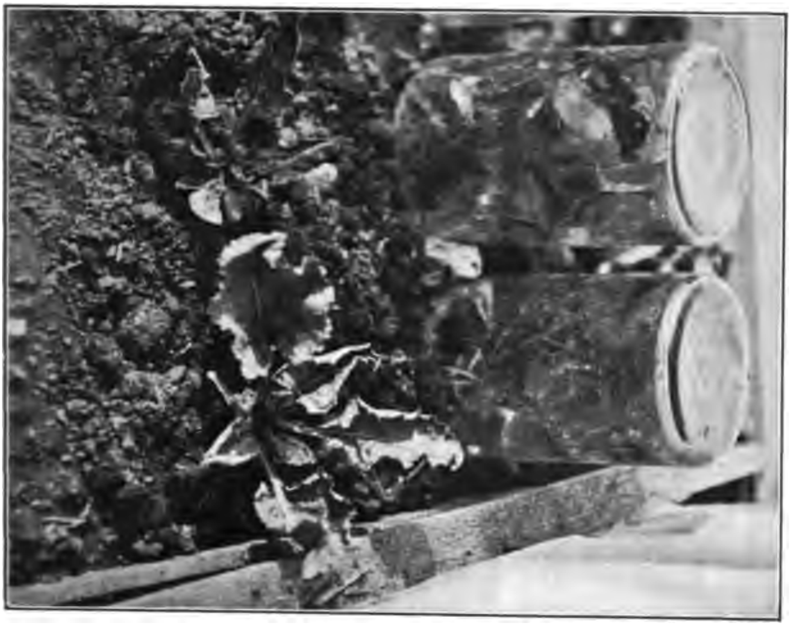

FIG. 1.—TWO YOUNG SUGAR BEETS SHOWING CURLY-TOP SYMPTOMS UNDER TEST CONDITIONS WITH LEAFHOPPERS.

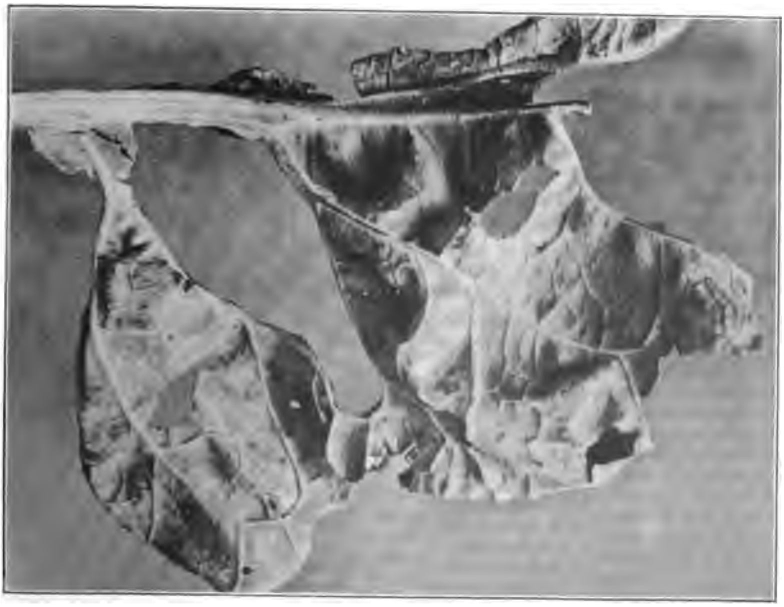

FIG. 2.—PORTION OF A CABBAGE LEAF SHOWING CURLY-TOP SYMPTOMS AFTER LEAFHOPPER ATTACKS; NO VISIBLE SPOTTING OF LEAVES.

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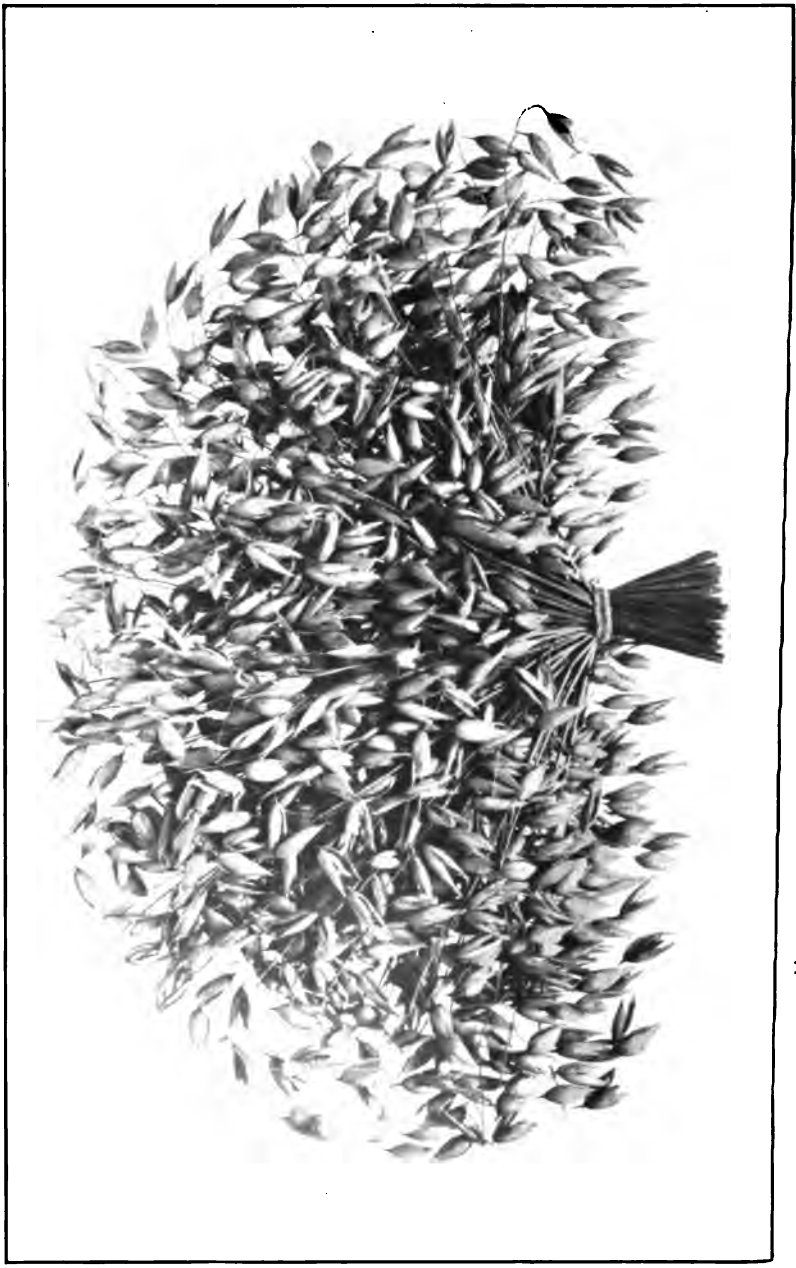
PLATE I.



Heads of the Swedish Select Oat Grown at Sitka, Alaska, in 1903.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 28, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Ten Years' Experience with the Swedish Select Oat," by Mr. Mark Alfred Carleton, Cerealist in Charge of Grain Investigations, and to recommend that it be published as Bulletin No. 182 of the series of this Bureau.

Twelve years or more ago, while considerable attention was paid to the oat crop in this country, there was no definite idea of the adaptation of varieties to different portions of the United States and there was great need of varieties that would give much better results in certain localities than were obtained by those then grown. About that time several different kinds of wheat, oats, barley, and other cereals were introduced into this country, particularly from Russia. Among these was the Swedish Select oat, obtained by the writer of the accompanying paper while acting as Agricultural Explorer for this Bureau. This soon proved to be admirably adapted to the northern portion of the United States.

This paper discusses the many experiments and observations made concerning this oat at several of the experiment stations and on numerous farms during the past ten years.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—566.

TEN YEARS' EXPERIENCE WITH THE SWEDISH SELECT OAT.

INTRODUCTION.

In the region between the Great Lakes and the Rocky Mountains one of the best-known varieties of oat at present is the Swedish Select. The annual production of this variety in the area mentioned is already at least 50,000,000 bushels, and in certain localities it has for some time entirely replaced all other kinds. It is the most popular oat in Wisconsin and adjacent districts, and the acreage sown each year has increased rapidly. Yet up to 1899 this oat was quite unknown in North America.

The Swedish Select oat was introduced into the United States by the writer in the spring of 1899 in time for planting that season. It was obtained, along with other cereals, while making an exploration of the cold and semiarid regions of Russia and western Siberia in 1898–99 in search of cereals adapted to corresponding conditions in this country. At the same time two other oat varieties were obtained, one of which, the Tobolsk, is of much value, but the Swedish Select is proving to be by far the best of the three in nearly every respect. It originated in Sweden as a pedigree variety developed by selection many years ago and was afterwards grown in Finland and in St. Petersburg Province, Russia. Under the severe weather conditions of these localities it became well acclimated for a cold and dry climate.

CHARACTERISTICS.

The Swedish Select variety is a large-grained white oat, with a spreading top or panicle. (See Pl. I.) The distinguishing marks are a blunt, plump kernel, with, usually, dark, slightly twisted awns and a heavy weight per bushel. It is a very prolific variety, which quality, together with the size and weight of the kernel, is no doubt the result of previous selection. The usual weight per bushel is 34 to 36 pounds, while in Montana a weight of 44 to 46 pounds is not rare. In order, therefore, to appreciate its real superiority over other varieties in yield per acre, comparison must be made on the basis of bushels by weight instead of measured bushels. It also grows to a considerable height and produces much straw, its chief fault being a tendency toward overproduction of straw when grown on rich or low land. The roots are large and vigorous, giving the plants hardiness in cold or dry seasons. This quality was probably developed during the period of acclimation in northern Russia. Plate II shows a sample of the Swedish Select oat in comparison with two other introduced oats, Sixty-Day and North Finnish Black.

RESULTS OF TRIALS IN THIS COUNTRY.

Only 20 bushels of seed of the Swedish Select oat were obtained in the original introduction.[a] One other importation of 160 bushels was made through Mr. E. A. Bessey in 1901.[b] However, a large percentage of the present production has descended from the 20 bushels received in 1899.

In another publication of this Department[c] the following statement by the writer is made at the close of a description of this oat:

> In this country it will be suitable for cultivation in all the extreme Northern States, from New York to Washington, and in southern Alaska.

With the exception that northern New England might have been included, no statement could be more completely and accurately confirmed by present results than this one has been after ten years of experience. The results of a long series of trials show that this variety is sharply limited in its adaptation to just the region mentioned and that it is not only much superior to other kinds previously grown in that region but is just as much inferior to other kinds in adaptation to other regions. It is just as worthless for Texas and Tennessee as it is superior for Wisconsin and Montana.

The whole series of trials of the Swedish Select oat in the United States and the accompanying results have been extremely interesting. No other introduced oat has been so thoroughly and widely tested.[d]

This oat was grown on the experimental plats of the Agricultural Academy at Moscow, Russia, and was considered by Professor Williams, of that institution, to be an excellent variety for the North.

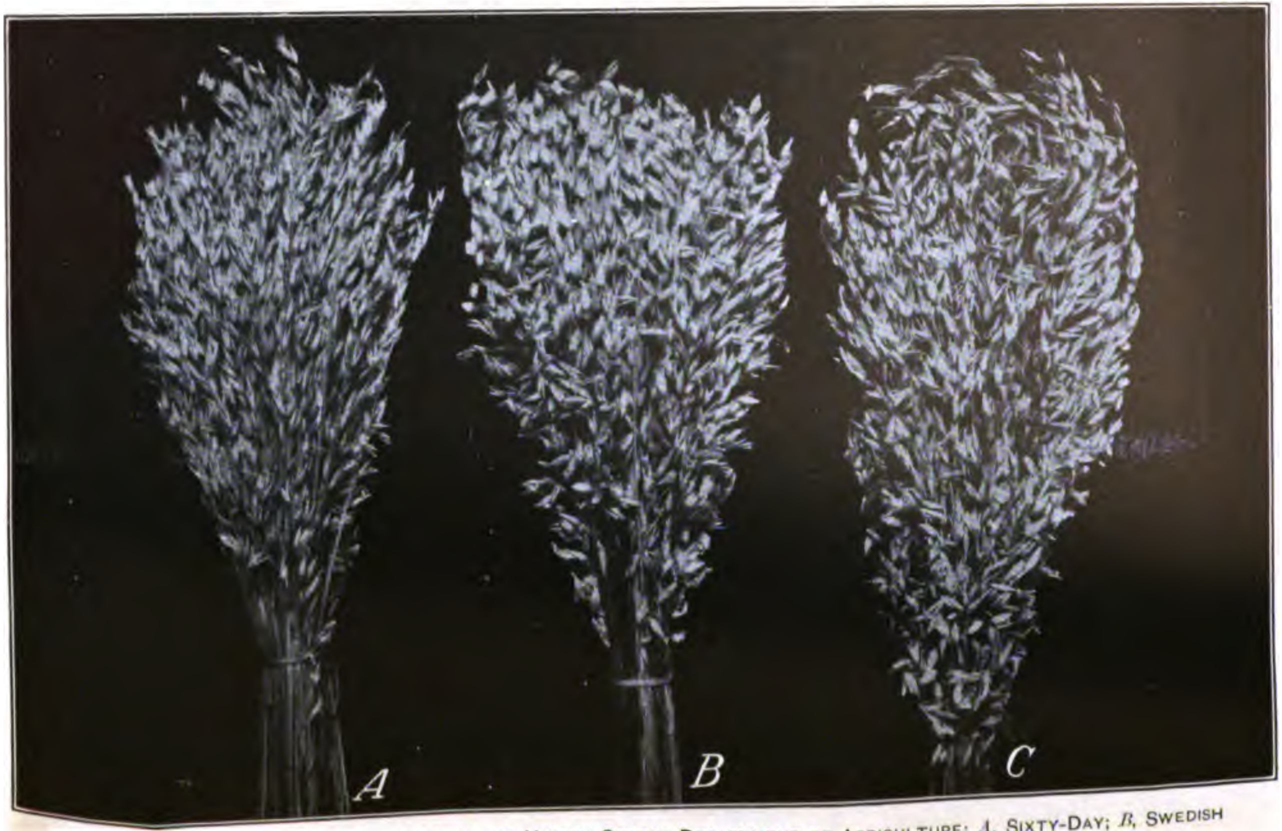
---

[a] Inventory No. 4, Division of Botany, U. S. Dept. of Agriculture, 1899, p. 3 (S. P. I. No. 2788), and Inventory No. 7, same series, 1900, p. 13 (S. P. I. No. 2788).

[b] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 276 (S. P. I. No. 9422).

[c] See "Russian Cereals Adapted for Cultivation in the United States," Bulletin 23, Division of Botany, U. S. Dept. of Agriculture, 1900, p. 21.

[d] It may be of interest, however, to state that another variety, the Sixty-Day, also from Russia, stands second in the attention it is receiving and promises to become fully as popular as the Swedish Select, although it is adapted to conditions largely just the opposite of those required by the latter oat.



THREE VARIETIES OF OATS INTRODUCED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE: *A*, SIXTY-DAY; *B*, SWEDISH SELECT; *C*, NORTH FINNISH BLACK.

TRIALS BY EXPERIMENT STATIONS.

A large part of the seed of the first introduction was placed immediately with the agricultural experiment stations in the Northern States and planted in the spring of 1899. From this time forward the most extensive trials have been made at the experiment stations in Wisconsin, North Dakota, and Montana. A report of these trials will be given. In Wisconsin and North Dakota the experiments have for some time constituted a part of the regular series conducted in cooperation with this Bureau.

WISCONSIN.

The results obtained by the Wisconsin Agricultural Experiment Station have been exceedingly interesting. Only 6 pounds of seed were sent to the station, and this quantity was sown on a tenth-acre plat. In the words of Prof. R. A. Moore, agronomist—[a]

> The results were so favorable that an effort was put forth to improve them by selection and careful grading of the seed for each season's crop. In all comparisons with selected varieties of oats the Swedish were equal to the best in point of yield and had several desirable characteristics superior to other varieties.

Concerning the good qualities of this variety, Professor Moore states as follows:[b]

> The Swedish Select oats (Wisconsin No. 4) seem especially adapted for high, well-drained land, and the best-known returns are from clay-loam soils. The great root development is one of the characteristics of the Swedish oats, which enables the plant to resist drought better than any other variety tested. The straw is coarse and is noted for its stiffness and power to withstand lodging. The Swedish oats lodged for the first time during the four years' test on the experimental farm the past season, this being due to the severe storm of July.

On the experiment station farm such good results were obtained in 1899 and 1900 that 7½ acres were sown in 1901, with the view of increasing the quantity of seed for distribution throughout the State. This crop made 306 bushels, a yield of 40.8 bushels per acre, in spite of the serious drought of that season. This drought, though it appears to have been particularly severe at Madison, where this good crop of Swedish Select oats was grown, was general throughout the State and, in fact, throughout the Northwest. The average yield of oats for the State was thereby reduced to less than 30 bushels per acre. There is shown, therefore, in this comparison a striking exhibition of the drought-resisting quality of the Swedish Select.

In the mean time there was organized the Wisconsin Agricultural Experiment Association, composed of people connected with the Wisconsin College of Agriculture, which association has become extremely effective in improving the crops of the State. Seed of the Swedish Select oat was sold to members of this association, and in 1902 forty-one members grew this oat in thirty-three different counties of the State. The average yield per acre from all these trials was 53 bushels, while the average yield of ordinary oats for the State was 40 bushels. No doubt a part of this difference in yield should be credited to the better methods of cultivation that would likely be practiced by these men, but it is probable that the larger percentage of increase was due to the variety employed. In 1903, 1904, and 1907 certain members of the association grew other varieties in comparison with the Swedish Select, with results here tabulated as follows:

---

[a] Third Annual Report, Wisconsin Agricultural Experiment Association, p. 9.

[b] First Annual Report, Wisconsin Agricultural Experiment Association, p. 16.

1903.

Number of members reporting	100
Number of acres sown	538¼
Number of bushels harvested	23,705
Average number of bushels per acre of Swedish Select	44
Average number of bushels per acre of other varieties	37.5

1904.

Number of members reporting	30
Number of acres sown	352
Number of bushels harvested	18,300
Average number of bushels per acre of Swedish Select	45
Average number of bushels per acre of other varieties	40

1907.

Number of members reporting	96
Number sowing on fall-plowed land	64
Number sowing on spring-plowed land	32
Number sowing with a drill	44
Number sowing with a seeder	46
Number treating for prevention of smut	25
Number of cases where oats were smutted	17
Number of cases where oats rusted badly	61
Average number of bushels per acre of Swedish Select	27.9
Average number of bushels per acre of other varieties	24.3

Seed has been sold by members of the experiment association to other farmers of the State, until the Swedish Select oat has become very widely distributed. Professor Moore estimates that 150,000 bushels were grown in 1903, 4,000,000 bushels in 1904, and in 1905 8,000,000 bushels by at least 10,000 farmers. In 1906 about 12,000,000 bushels were produced, and in 1907 at least 20,000,000 bushels, though the season was very unfavorable. In 1908 no less than 30,000,000 bushels were harvested, or over two-fifths of the entire oat crop of the State. These estimates refer only to the crop descended from the original 6 pounds of seed sent to the experiment station. There is a considerable production in Wisconsin descended from other seed and referred to in another place. About three-fourths of the members of the Wisconsin Agricultural Experiment Association were growing the Swedish Select oat in 1908.

The results of a 10-year yield test of the Swedish Select oat in comparison with that of a number of other good varieties at the Wisconsin Agricultural Experiment Station are summarized below in bushels per acre, the average yield for the State being given also for further comparison:

TABLE I.—*Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the Wisconsin Agricultural Experiment Station and throughout the State from 1899 to 1908, inclusive.*

Year.	Swedish Select.	Highest yield of any other variety.	Average of all other varieties.	Average yield of oats in Wisconsin.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
1899	50.6	65.0	49.4	36.0
1900	64.5	79.2	49.4	32.0
1901	38.1	46.8	30.2	29.1
1902	69.2	61.3	46.1	39.9
1903	72.0	72.5	59.0	32.8
1904	62.0	64.0	50.3	35.0
1905	50.0	66.8	43.4	39.0
1906	39.0	78.1	32.6	37.4
1907	12.5	33.7	17.5	22.0
1908	50.0	63.6	45.0	31.1
Average	50.8	63.1	42.3	33.4

Table I shows that the yield per acre of the Swedish Select oat as an average for 10 years is 50.8 bushels and is 8.5 bushels greater than the average yield of all other varieties tested during this time. An average of the highest yield reached by any other variety during the period is 63.1 bushels. This statement must not be misunderstood. The highest yield was not made by the same variety each year. The Swedish Select made the greatest average yield for the 10-year period. With reference to the yield of the Swedish Select oat in 1907, Professor Moore comments as follows:

> Our test plots were located in a hollow, and the heavy rains during the summer partially flooded some of the ground, and the oats were badly lodged and affected with rust to such an extent that the crop was almost a failure. A member of our experiment association, who lives near the university farm, has been carrying on tests with these (Swedish Select) oats for several years under our direction. I almost think it would be fair to use his figures in this report as he has been carrying on his work in accordance with my directions for several years. His report on 18 acres this year with the Swedish Select oats is 33 bushels to the acre.

The seven varieties yielding the highest per acre for the period 1899–1903 are as follows:

	Bushels.
Swedish Select	58.8
Big Four	56.3
Silver Mine	55.6
Early Gothland	54.8
Lincoln	53.6
Wisconsin Wonder	53.5
Siberian	53.0

The figures for the Swedish Select and the Siberian varieties are for the full 5-year period. The other varieties, except the Wisconsin Wonder, were sown first in 1900, and the average yields are therefore for 4 years only, while the Wisconsin Wonder was grown only in the 3 years from 1901 to 1903. The same varieties made the highest yields for the 7-year period from 1899 to 1905, but in the following order:

	Bushels.
Swedish Select	58.1
Wisconsin Wonder	56.1
Big Four	55.3
Siberian	54.9
Early Gothland	53.5
Lincoln	53.3
Silver Mine	50.9

The Swedish Select is the only one of the seven varieties that was grown every year of this period. The Siberian, Early Gothland, and Silver Mine were grown for 6 years, and the Wisconsin Wonder, Big Four, and Lincoln for 5 years. The average yield per acre of the Swedish Select oat for 7 years is 2 bushels greater than that of the Wisconsin Wonder, standing next highest, though from fifteen to thirty-five good varieties were compared during this time, while during 8 years it averaged 3.3 bushels per acre more than the Siberian, which yielded next highest for that period.

Such figures as the foregoing do not, however, give an accurate idea of the yields, as all varieties are not always grown the same years. By substituting Tobolsk for Lincoln we have seven kinds, some or all of which have been grown every year of certain periods. For example, the seven were grown each of the 6 years from 1901 to 1904, 1906, and 1907, with average yields per acre as follows:

	Bushels.
Swedish Select	59.5
Wisconsin Wonder	47.3
Siberian	44.1
Early Gothland	42.5
Big Four	41.6
Silver Mine	40.8
Tobolsk	36.1

Six of these seven varieties were each grown every year of the 7-year period from 1900 to 1904, 1906, and 1907, and another series of six was grown every year of the 7-year period from 1901 to 1904 and from 1906 to 1908, with yields as follows:

Period, 1900–1904, 1906, and 1907.

	Bushels.
Swedish Select	60.2
Big Four	46.3
Siberian	45.1
Silver Mine	45.0
Early Gothland	43.6
Tobolsk	38.7

Period, 1901-1904 and 1906-1908.

	Bushels.
Swedish Select	58.2
Wisconsin Wonder	46.0
Early Gothland	43.1
Big Four	42.4
Silver Mine	42.2
Tobolsk	36.8

Five of these seven varieties were grown every year of an 8-year period, 1900–1904 and 1906–1908, with the following average acre yields:

	Bushels.
Swedish Select	58.9
Big Four	46.7
Silver Mine	45.7
Early Gothland	44.0
Tobolsk	39.2

Three varieties were grown every year of the 9-year period from 1900 to 1908, with yields as follows:

	Bushels.
Swedish Select	57.9
Silver Mine	44.9
Early Gothland	43.3

The Swedish Select is the only variety grown during the entire 10-year period from 1899 to 1908, giving an average acre yield of 50.8 bushels, as already mentioned. (See Pl. III.)

This summary of the tests at the Wisconsin Agricultural Experiment Station, in which many good varieties were employed, indicates a complete victory for the Swedish Select oat. To give an average yield during 9 years of 13 bushels more than the Silver Mine, and during 8 years of 12.2 bushels more than the Big Four, which the Swedish Select has done, is an indication of exceptional merit, as these two oats are considered among the best in the North-Central States. The Wisconsin Wonder stands high in one of the 7-year periods and is apparently a good oat.

The Sixty-Day oat was grown each year of the last 4 years, 1905–1908, and during these years gave an average yield of 59.1 bushels, considerably larger than that of the Swedish Select for the same period. This period, however, includes particularly unfavorable years for the latter, compared with other sorts. During an 8-year period the Swedish Select oat gave an average yield almost equal to that of the Sixty-Day for the 4 years from 1905 to 1908.

NORTH DAKOTA.

A valuable characteristic of the Swedish Select oat is its hardiness in seasons of drought and cold and its ability to produce well on high, poor land. On the other hand, under very favorable conditions for oat production it is likely to prove inferior to other good varieties.

This fact is well illustrated in the results obtained at the North Dakota Agricultural Experiment Station at Fargo. This experiment station is located in the Red River Valley, a region of low elevation, having a rich, black soil and a good average rainfall. In recent years the rainfall has been considerably above the average, finally resulting in 1905 in actual inundations of portions of the valley, including the site of the experiment station. Accordingly, no comparison of yields of oats can be given for 1905. The loss of seed by fire prevented the sowing of the Swedish Select variety in 1901. For the remaining years from 1899 to 1908 the yield per acre of the Swedish Select, compared with other varieties, is as follows:

TABLE II.—*Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the North Dakota Agricultural Experiment Station and throughout the State from 1899 to 1908, except 1901 and 1905.*

Year.	Yield of Swedish Select.	Highest yield of any other variety.	Average yield of all other varieties.	Average yield of oats in North Dakota.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
1899	75.4	81.1	70.7	30.0
1900	23.0	45.7	29.1	10.3
1902	30.8	72.2	40.7	38.4
1903	68.2	77.3	62.8	27.4
1904	54.6	75.4	57.8	37.4
1906	48.1	55.6	46.6	32.5
1907	58.7	78.0	58.1	24.5
1908	67.0	95.2	79.8	23.4
Average	53.2	72.6	55.7	28.0

It will be observed that here the Swedish Select compares unfavorably with other varieties, its yield per acre being less than the average for all others in the years 1900, 1902, 1904, and 1908, and its average for the 8 years less by 2½ bushels than the average for all other varieties for that period. It remains, however, pretty nearly an average variety in yield for that region, and is superior to many others in size and weight of kernel. As might be supposed, it has done much better in higher and drier portions of the State westward. Prof. J. H. Shepperd, collaborator in these investigations, writes as follows:

> The Swedish Select oat has not proven a very good variety under local conditions. It does far better on our lighter and drier soil.

At the branch experiment station at Edgeley, N. Dak., in 1903 and 1904 this variety gave good results, making a yield per acre considerably greater than the average of all other varieties. (See fig. 1.)

MONTANA.

At the Montana Agricultural Experiment Station, at Bozeman, the conditions for oat cultivation are even more favorable ordinarily than at Fargo, N. Dak. Here, also, in a 5-year trial the Swedish Select oat gave yields inferior to those of a number of other varieties. In

FIELD OF SWEDISH SELECT OATS ON THE EXPERIMENT STATION FARM AT MADISON, WIS., IN 1906.

(From a photograph furnished by Prof. R. A. Moore.)

addition to the low-lying rich soil and excellent climate the oat plats had the advantage of irrigation. Other trials by farmers in other parts of the State were made under conditions of "dry farming" without irrigation. Results are available only for the period from 1900 to 1905, inclusive, and through some oversight the Swedish Select variety was not sown at the experiment station in 1902. This happened, too, to be a year of enormous yields, one variety, the Wide Awake, yielding 172.5 bushels per acre. For the remaining years in this period from 1900 to 1905 the yield of the Swedish Select, compared with five other varieties, was as follows:

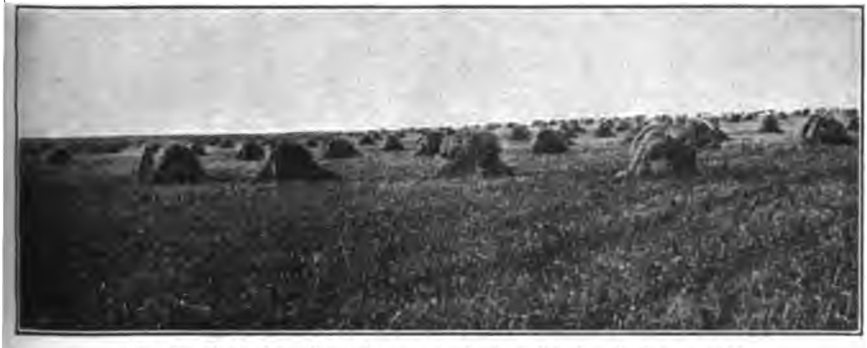


FIG. 1.—Field of Swedish Select oats in shock, at Edgeley, N. Dak., in 1904.

TABLE III.—*Yield to the acre of the Swedish Select oat compared with that of five other varieties grown at the Montana Agricultural Experiment Station during 1900 and 1901 and from 1903 to 1905.*

Variety.	1900.	1901.	1903.	1904.	1905.	Average.	Weight per bushel.	Period of growth.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bushels.*	*Pounds.*	*Days.*
Progress	93.2	92.4	127.5	137.4	112.5	112.6	41.6	118.0
White Danish	99.5	92.4	114.4	135.2	138.8	116.1	41.1	118.0
Wide Awake	79.6	94.3	120.0	141.7	115.6	110.2	41.9	117.0
Scotch	79.6	95.2	97.5	153.4	112.5	107.6	41.5	116.0
Swedish Select	93.2	100.2	99.4	133.4	108.8	107.0	44.1	111.5
Bland's White	95.6	87.7	113.4	113.1	112.5	104.5	40.6	122.0

The Swedish Select oat stands fifth in the list in yield. These varieties only were grown in 1905. For the years 1900, 1901, 1903, and 1904 the following other varieties made an average yield greater than that of the Swedish Select, while several fell below it:

	Bushels.
Mogheda	109.8
American White	109.2
American Beauty	107.9
Archangel	106.9

It will be noted in Table III that the Swedish Select oat stands much above the others in weight per bushel. It is also four days earlier than any other variety. Only one variety out of fifteen, the

Badger Queen (not grown in 1905), weighed more than the Swedish Select, the average weight of the former for four years being 44.5 pounds per bushel.

SOUTH DAKOTA.

Next to Wisconsin, more attention has been given to the Swedish Select oat at the South Dakota Agricultural Experiment Station, at Brookings,[a] than at any other point. Here this oat has been grown throughout the 10-year period from 1899 to 1908, but in 1902 no results were reported because of the damage by wind, and in 1903 all varieties were entirely destroyed by hail. Therefore, actual results are available for only 8 years out of the 10.

During the period mentioned, 1899–1908, many varieties of oats were grown, a number of them having just been introduced by the writer from Russia and other foreign countries. In the following table is given the yield per acre obtained with some of the best sorts, only two of which, the Swedish Select and the Tobolsk, were grown each of the eight years.

TABLE IV.—*Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the South Dakota Agricultural Experiment Station from 1899 to 1901 and from 1904 to 1908.*

Variety.	1899.	1900.	1901.	1904.	1905.	1906.	1907.	1908.	Average.	Number of years grown.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bushels.*	
Swedish Select	41.65	22.7	59.0	70.0	45.3	61.6	24.1	25.0	43.67	8
Tobolsk	35.50	24.3	57.0	55.6	40.6	47.5	5.0	21.8	35.91	8
Sixty-Day			65.0	69.6	80.0	61.6	24.4	59.2	59.96	6
Lincoln, No. 151				50.7	24.3	42.2	14.1	17.6	29.78	5
White Schoenen, No. 153				46.8	20.6	19.4		8.4	23 8	4
Bavarian, No. 150				46.8	30.2	32.7		13.4	30.77	4
Banner, No. 160				54.7	35.2	42.7	8.1	2.5	28.64	5
American Triumph, No. 162				52.7	30.5	45.5	10.9	4.3	28.78	5
American Beauty, No. 163				55.6	28.7	43.8	10.3	5.0	28.68	5
North Finnish Black				65.0	35.7	40.8	5.0	20.6	33.42	5
Holstein Prolific, No. 158				55.6	22.8	44.4	11.9	5.4	28.02	5
Wide Awake, No. 154				51.7	24.1	35.0	11.9	12.5	27.04	5
Abyssinian, No. 155				54.7	25.6	37.2	14.4	16.2	29.62	5
Columbus, No. 156				58.6	31.9	42.8	17.8	15.0	33.22	5
Golden Beauty, No. 159				56.6	27.5	42.4	13.8	6.2	29.3	5
Belyak, No. 10624				28.0	37.5	42.8	9.1	26.8	28.84	5

It is seen that the Swedish Select variety yielded better than any other oat except the Sixty-Day, which gave a much better average for the years it was grown, 1901–1908. During these same years the Swedish Select average was 47.5 bushels, while 59.96 bushels was the

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[a] All the experiments were cooperative between this Bureau and the state experiment station and were undertaken with Prof. E. C. Chilcott (now of this Bureau) in charge of the department of agronomy at the state station and were continued afterwards while his former assistant, Mr. J. S. Cole, was in charge of the same department. Early in 1908 Prof. C. Willis was elected to this position, and beginning with the season of 1909 all cooperative experiments with the Office of Grain Investigations have been concentrated at Highmore, S. Dak., with Mr. Manley Champlin, special agent of this Bureau, in immediate charge.

Sixty-Day average. The latter is already to a large extent replacing the former in eastern sections of the State. Until recently the Swedish Select has been by far the most popular oat and is still largely employed in the drier districts. It is an attractive oat, because of the size and weight of its kernel and its usual freedom from discoloration. The Tobolsk and the North Finnish Black, standing third and fourth in rank, respectively, are also northern varieties adapted to cool, dry seasons and high plains. (See Pl. II.)

Through the medium of the state experiment stations a considerable distribution of seed of the Swedish Select oat was made to farmers in South Dakota and North Dakota. Concerning this distribution in South Dakota, Mr. J. S. Cole wrote as follows:[a]

> It was distributed in this State by the state experiment station in 1901. In 1902 a more extensive distribution was made, and every year since several hundred bushels have been sold to farmers by the station. In the western part of the State it has made a good crop in years when the common varieties were a total failure, but in the eastern and southeastern portions of the State in years of excessive moisture it is likely to grow too rank and to be damaged by rust. It is no more subject to damage in this way, however, than are all common varieties of oats.

At the branch experiment station at Highmore, S. Dak., the Swedish Select oat was grown during the period from 1903 to 1909, inclusive.[b] Here the conditions are usually severe for oat growing, and this variety gave good results compared with others, as is shown in the following table:

TABLE V.—*Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the branch experiment station at Highmore, S. Dak., from 1903 to 1909, inclusive.*

Variety.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	Average for 4 years (1906–1909).	Average for 5 years (1905–1909).	Average for 7 years (1903–1909).
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Swedish Select	38.1	54.4	55.0	65.0	30.8	32.9	36.6	41.3	44.1	44.7
Sixty-Day	24.1	41.3	64.1	*43.3	31.5	47.5	28.8	37.8	43.1	40.2
Kherson				69.7	28.7	45.8	21.9	41.5		
Red Algerian			60.3	49.1	21.8	32.8	23.4	31.8	37.5	
Belyak			52.5	55.6	26.5	21.3	22.8	31.6	35.7	
Golden Beauty				60.3	26.5	27.5	17.2	32.9		
American Beauty				47.8	35.3	25.3	20.3	32.2		
American Triumph				49.4	31.5	26.3	20.3	31.9		
Columbus				52.5	25.0	28.1	16.3	30.5		
Lincoln				45.6	30.6	29.7	15.6	30.4		
Danish				46.3	26.8	30.3	15.0	29.6		
Canadian				52.2	23.4	30.3	12.5	29.6		
Holstein Prolific				48.8	26.2	22.5	17.8	28.8		
Abyssinian				50.9	25.3	25.0	12.8	28.5		
Wide Awake				42.5	24.6	28.9	10.6	26.7		
White Tartar				44.7	26.2	25.0	4.7	25.2		

* This yield of the Sixty-Day oat is not comparable with any of the others for that year, as it was grown after sorghum, while all the others were grown under better conditions. This is proved by the fact that the Swedish Select was duplicated on the sorghum ground and made there only 42.8 bushels per acre. However, using this figure the 7-year average, 41.5 bushels, thus resulting for the Swedish Select is still somewhat larger than that for the Sixty-Day.

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[a] Bulletin 96, South Dakota Agricultural Experiment Station, March, 1906, p. 54.

[b] The tabulations in this bulletin usually do not go further than the year 1908, but there are so few years' results at Highmore, S. Dak., that it seems necessary to include here the year 1909.

Taking an average of all trials in each case, the Swedish Select variety gave the best yield, though the Kherson yielded a trifle better in the 4-year average, 1906–1909. The yield of the Swedish Select at Highmore in 1903 was not quite as good as the average oat yield throughout the State (38.6 bushels), because of severe drought in that district. Highmore is considerably west of the one hundredth meridian, where it is ordinarily very dry for oats. On the other hand, in 1905 (a wet season) and 1908 the Sixty-Day exceeded the Swedish Select in yields. With reference to the crop of 1903, Prof. E. C. Chilcott wrote as follows:

> It is worthy of note that at the driest time the Swedish Select oat appeared to be the most drought-resistant grain on the farm, with the Minnesota No. 6 Manchuria barley a close second. This appearance was borne out by the yields at harvest time.

WASHINGTON.

The Swedish Select oat was grown on the Washington Agricultural Experiment Station farm at Pullman during three seasons. In 1903 it made 55 bushels per acre. In 1904 it yielded 86 bushels, in comparison with 82.5 bushels as the highest for any other variety and an average of 61.3 bushels for all other kinds. In 1905 it yielded 53 bushels, the same as the average for all others, while it was exceeded by one variety, the Sixty-Day, which yielded 84 bushels. The average yields for the State during these years were 47.9 bushels in 1903; 44.9 bushels in 1904; and 50 bushels in 1905. The results reported by farmers from other portions of the State where the climate is drier were much more to the credit of the Swedish Select.

COLORADO.

In 1900 the Swedish Select oat yielded 18 bushels per acre at the branch experiment station at Cheyenne Wells, Colo., where, at that time, it was hardly expected that any cereal crop would produce anything. The average yield of this variety at the Colorado Agricultural Experiment Station, at Fort Collins, for the years from 1905 to 1907 was 88.4 bushels, the average of all other varieties being 86.8 bushels for the same period.

IOWA.

As already mentioned, the Swedish Select oat is adapted particularly to the Northern States. Iowa may be considered as a transition area between the northern and central districts (see fig. 2). As might be expected, therefore, this oat does not compare quite so well with other varieties in that State as farther north, but nevertheless ranks rather high in acre yields. In the several years' experiments conducted at Ames by the Iowa Agricultural Experiment Station, some results of which were published by Prof. M. L. Bowman in a

'Seed Oat Special," it was found to stand third in yield among sixteen good varieties as an average of four years' trials, 1905–1908.

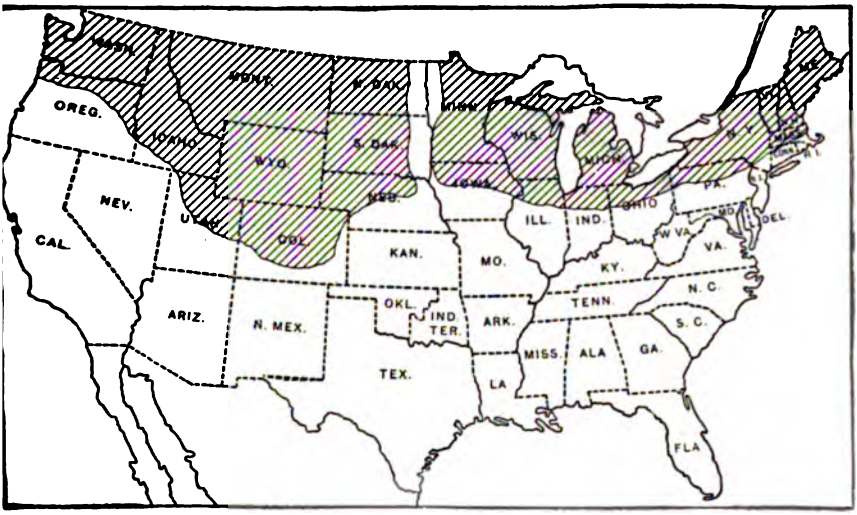


FIG. 2.—Map of the United States, the shaded portion showing the region to which the Swedish Select oat is adapted.

The following is a tabular statement of the average date of ripening, acre yield, and weight per bushel of the sixteen varieties:

TABLE VI.—*Average date of ripening, acre yield, and weight per bushel of the Swedish Select oat compared with those of fifteen other varieties grown at the Iowa Agricultural Experiment Station from 1905 to 1908, inclusive.*

Variety.	Average date of ripening.	Average yield per acre.	Average weight per bushel.
		Bushels.	*Pounds.*
Kherson	July 15	60.2	30.00
Silver Mine	July 23	56.0	27.00
Swedish Select	July 24	50.5	29.50
Sixty-Day	July 15	48.7	29.75
Minnesota, No. 25	July 24	47.6	25.25
National	July 25	47.4	28.00
White Alaska	July 14	47.0	30.75
Irish Victor	July 24	46.9	25.50
White Russian	July 30	46.3	26.50
Minnesota, No. 6	July 24	45.7	27.00
Joanette	July 26	45.3	27.75
Siberian	July 25	44.5	25.75
Early Champion	July 14	44.4	29.50
Tartar King	July 22	40.1	27.25
White Tartar	July 30	37.4	28.75
Danish	July 25	35.2	24.00

Table VI shows that only two varieties, the Kherson and the Silver Mine, exceed the Swedish Select in acre yields, and only three, the White Alaska, the Kherson, and the Sixty-Day, exceed it in weight per bushel. It may be considered, therefore, as one of the best varieties for Iowa, but not absolutely the best.

ALASKA.

Under the direction of Prof. C. C. Georgeson, Special Agent in charge of the Alaska Agricultural Experiment Stations, the Swedish Select oat has been tested at one or more points in Alaska in competition with other varieties during the entire period from 1900 to 1908, except the season of 1901. In nearly all cases it either partially or fully matured, though in three instances it appears to have failed completely—at Kenai in 1903, at Sitka in 1904, and at Rampart in 1905. In two of these instances all other varieties also failed.

The weather conditions at Copper Center, though south of Rampart, are more severe than at the latter place, and cereals have usually done better at Rampart. Nevertheless, the Swedish Select oat at Copper Center was cut for seed in 1904 and gave a "good average crop," the plants being "well filled." The plants matured also in 1905 and partially matured in 1906 and 1907. The North Finnish Black, another variety introduced by this Department, is the only one that has been constantly more successful than the Swedish Select.

The specimen of the Swedish Select oat shown in Plate I was grown at Sitka in 1903.

MISCELLANEOUS.

In some other States entirely outside of the northern oat district, such as Indiana and Ohio, the Swedish Select stands still farther removed from the top in yielding capacity in comparison with other kinds, according to results at the experiment stations, but even in those States gives results usually considerably better than the average.

TRIALS BY FARMERS.

While the tests of any crops made by farmers are not likely to be so accurate as a rule as those made at experiment stations, nevertheless more satisfactory information may often be obtained from such tests because of their greater number and the fact that they represent such a variety of conditions of soil and climate. The system of securing, filing, and summarizing reports devised in the Office of Grain Investigations and used in cooperation with the Office of Seed and Plant Introduction and Distribution has made it possible to obtain a great amount of interesting information concerning this new oat variety.

It may be of value to the reader to give extracts from some of the most important reports on the Swedish Select oat received from farmers.

WASHINGTON.

Mr. Gilbert Engbritson, of Edison, Skagit County, Wash., 80 miles north of Seattle, wrote as follows on September 15, 1904:

> I beg to make a second report to your Department on the results of the second crop of the 2 pecks of No. 9422 Swedish Select oats mailed to my address February 16, 1903.

The 2 pecks planted in 1903 produced the seed for planting 7 acres in 1904, which were thrashed on the 12th instant, yielding 1,050 bushels, averaging 150 bushels per acre—a remarkable yield of bright, heavy oats of excellent quality which has attracted the attention of the entire community.

In 1906 Mr. Engbritson harvested 7,987 bushels, yielding 126 bushels per acre.

Mr. Anton Lehnhoff, of Mount Vernon, Wash., bought seed from Mr. Engbritson and in 1903 obtained a crop of 9,600 bushels, at the rate of 90 bushels per acre, while other varieties on the same farm made 75 bushels.

IDAHO.

Mr. F. W. Boehme, of Geneva, Idaho, has been a very successful cooperator in trials of different cereals received from this Department. His farm lies along the Thomas Fork of the Great Bear River, in extreme southwestern Idaho, at an elevation of 8,000 feet. On December 26, 1905, he wrote the following statement:

> The Swedish Select oats yielded 1,988 pounds from 61¼ pounds of seed (corresponding to at least 65 bushels per acre), all nice, white, and heavy grain.

Clark and Haughton, of St. Anthony, Idaho, thrashed 8,000 bushels of the Swedish Select in 1905, yielding 65 bushels per acre. Other oats on similar soil and under similar treatment yielded 45 bushels per acre and weighed 5 pounds less per measured bushel.

Mr. J. D. Louis grew the Swedish Select oat 2 years at St. Anthony, Idaho. In 1906 a part of the crop was irrigated and a part not irrigated. A yield of 43½ bushels per acre was obtained on the irrigated land, compared with 35 to 40 bushels produced by other varieties. Another unirrigated field of 9 acres of the Swedish Select yielded at the rate of 70 bushels per acre, testing 40 pounds to the measured bushel.

In 1903 the average yield of the Swedish Select oat grown by several farmers at Blackfoot, Idaho, was 60 bushels per acre, as reported by Prof. H. T. French, of the Idaho Agricultural Experiment Station.

COLORADO.

Mr. C. H. Morgan, of Norwood, Colo., wrote as follows on December 27, 1905:

> A very fine early oat and of good weight, 45 pounds to the measured bushel. The 2 bushels you sent me weighed only 36 pounds to the bushel; therefore, I gained 9 pounds per bushel the first year.

Mr. Morgan obtained 60 bushels per acre, while other oats made 30 bushels. In 1906 he harvested 32 bushels on one-fourth acre which weighed 45 pounds per bushel, while other varieties yielded 40 bushels per acre.

Mr. T. A. Wright grew this oat two years at Greenwood, Colo. In 1906 he obtained one bushel of oats from a seeding of 6½ quarts, and in 1907 obtained 15 bushels from one-half acre, weighing 35 pounds to the bushel. He treated his oats thoroughly for smut prevention both seasons.

Mrs. S. B. Walker, of Sedalia, Colo., grew the Swedish Select oat two years, 1906 and 1907, beginning with a very small quantity of seed. In 1907 the total number of bushels thrashed was 270, and the yield per acre 45 bushels. The highest yield made by any other variety was 30 bushels—the Colorado White. Mrs. Walker writes as follows:

> There is no irrigation whatever on the place, and I am endeavoring to bring about strictly dry-farming cultivation, most of the so-called dry farming in the vicinity being simply the raising of crops without water without any regard to previous cultivation and preparation of land, and in almost every instance no regard is paid to the dry mulch.

At Lansing, in eastern Colorado, Mr. A. S. Kester grew the Swedish Select oat in 1903, obtaining a very small yield per acre, but explained it as follows:

> This was the only oat thrashed in this vicinity. We had no rain all summer. The season is considered the driest for the past 17 years with the exception of 1894.

Of the crop of 1904 Mr. Kester writes the following:

> Bushels thrashed, 68; yield per acre, 14 bushels. The oats did not come up till the first week in May. It was very dry here in early spring and after the middle of June.

Mr. J. A. Riedesel, of Idalia, Colo., began growing the Swedish Select variety in 1903 and finally, after two partial failures, obtained 300 bushels in 1905, that is, 30 bushels per acre, other varieties yielding 25 bushels.

MONTANA.

Mr. C. H. Austin, of Cascade, Mont., obtained 62 bushels per acre in 1902, when other kinds of oats yielded from 30 to 50 bushels. He writes as follows:

> These oats had no irrigation, nor were they on extremely low land. We treated them for smut with formalin and had no trace of smut.

Mr. W. W. Cook, of Chinook, Mont., reports as follows for 1903:

> Bushels thrashed, 800; yield per acre, 50 bushels, weighing 48 pounds per bushel. These are the finest oats I ever saw. I sent a sample to Bozeman the other day that weighed over 50 pounds per measured bushel.

At the same place, the same season, Mr. Rudolph Hermes thrashed 900 bushels, yielding 64 bushels per acre.

Mr. T. L. Black, of Whitehall, Mont., obtained 80 bushels per acre in 1904, weighing from 42 to 45 pounds per bushel. His remarks concerning the variety are as follows:

> This oat has proved to be extra early for me, and I consider it of great value in localities where water runs short for a second irrigation. The water was applied June 20. I also find that 1¼ bushels of seed per acre give better results when water is only available for one irrigation. Should be sown from April 1 to 10 when the above-mentioned conditions prevail.

Mr. J. J. Patterson, of Truly, Mont., obtained 90 bushels per acre in 1904 and reports a weight of 52 pounds per measured bushel.

At Bozeman, Mont., Mr. Jacob Carolus obtained 1,600 bushels of the Swedish Select oat on high land without irrigation, the yield being 40 bushels per acre.

MICHIGAN.

Mr. Marvin Babbitt, of Merson, Mich., reports as follows concerning his crop of 1903:

> Yield per acre, 48 bushels; quality of grain, excellent; average yield of other kinds in the same locality, about 30 bushels. The Swedish Select is decidedly the best grown in this locality. It is very plump and seems to possess all the properties an oat should have.

Mr. B. F. Beckwith, of St. Clair, Mich., obtained 80 bushels per acre in 1905, when other oats in the locality yielded only 30 bushels. He writes as follows:

> As I sowed the sample in 1904 I think it was rather a remarkable yield, considering the average yield of oats in this vicinity. If, when it becomes acclimated, it does half as well it will be remarkable.

In 1906 the yield per acre was 40 bushels, while other varieties on the same farm made 20 bushels. In 1908 occurred the greatest drought for many years. Even that season the Swedish Select yielded 40 bushels per acre.

Mr. James S. Bailey, of East Paris, Mich., at the end of four years' trial writes the following:

> I think these are the best oats that I have raised, and I shall sow mostly the Swedish Select this next year.

In 1906 Mr. Bailey's crop was 193 bushels, a yield at the rate of 37 bushels per acre.

Mr. R. D. Morrison, of Merle Beach, Mich., grew the Swedish Select oat during the years from 1906 to 1909, getting an average acre yield of 32.6 bushels. He writes concerning the 1907 crop as follows:

> I raised these oats in the same field as I did some Big Four oats and sowed them (the former) 2 weeks later, but they were ripe about the same time.

In 1908 the yield per acre was 35 bushels, while an adjoining field of another variety made 20 bushels per acre.

SOUTH DAKOTA.

Mr. H. C. Warner, of Forestburg, S. Dak., found the Swedish Select to be the best variety out of fifty-four under trial on his farm. In 1905 it yielded 75 bushels per acre, while other varieties made 50 bushels.

This oat was grown by Mr. G. A. Grant at Sherman, S. Dak., during 1906, 1907, and 1908. In the second year he obtained a crop of 913 bushels, averaging 40 bushels per acre. In 1908 the acre yield was the same and the total production 2,453 bushels. The only other variety grown on the same farm was the Sixty-Day, also introduced by this Department, which yielded 40 bushels per acre.

Mr. J. E. Behnke, of Beresford, S. Dak., grew the Swedish Select oat 7 years, 1903 to 1909, but no report is at hand of his 1906 crop. For the other 6 years his average yield per acre was 40.5 bushels, the separate yields being for 1903, 30 bushels; 1904, 55 bushels; 1905, 48 bushels; 1907, 50 bushels; 1908, 25 bushels; and 1909, 35 bushels. Yields of other varieties for certain years were as follows: 1903, 28 bushels; 1904, 41 bushels; 1905, 35 bushels; and 1908, 20 bushels.

Prof. J. H. Shepard, of Brookings, S. Dak., in addition to his official experience with introduced grains obtained through this Department, has taken much interest in a private way in trials on his own land of some of the best varieties. He states his experience with the Swedish Select as follows:

> I sowed some on corn ground, some on manured land, and some on very rich ground. My findings are as follows: Remember the season (1905) was excessively wet. After barley and after oats I got a good stand; the oats did not go down and the berries were plump and heavy. The same is true after wheat.
>
> On rich ground the oats lodged some in patches, but they all filled. On heavily manured land they went down in patches and they filled well, except where the lodged places occurred. On corn ground they lodged more, but not enough to prevent filling in the lodged places. On no kind of ground did they all go down, but in patches only. I believe that had the season been dry I would have had no lodged oats on any of these places and that the quality of the oats would have been all that could be desired. Naturally enough, the higher the ground the better the oats were during the past wet season. During dry seasons they might be sown on low land.
>
> The record of yields this year (1906) was somewhat lower than last, owing to my experimenting under different conditions and also to the fact that a slight hailstorm ruined many berries when they were just coming into milk. My yield this year was 65 bushels per acre, last year 75 bushels, while under the best conditions on our experimental grounds the yield rose to 84 bushels per acre. But the most remarkable thing to my mind is that on my old land, which had been systematically robbed by 25 years of wheating, the best yield of oats I ever could get was 40 bushels of White Russian oats, and I never equaled that figure with any other kind, and I tried all I could get. The first year the Swedish Select jumped immediately up to 75 bushels, while the station has shown that this is by no means the limit. I sowed but 2 bushels and 1 peck per acre, as they are heavy stoolers, but believe that heavier seeding will increase the yield.

Moreover, the analyses of these oats, as made in my laboratories, show them to be exceptionally rich in protein. It is for these reasons that we consider them to be the best all-around oats for the Dakotas. They mature in about 108 days.

NEW YORK.

An interesting 6-year trial of the Swedish Select oat was made by Mr. S. J. Smith at Manchester, N. Y., beginning in 1903. His yields per acre were 84 bushels in 1903, 80½ bushels in 1904, 70 bushels in 1905, 75 bushels in 1907, and 60 bushels in 1908, or an average for these five years of 73.9 bushels. No report is received for the year 1906. The average yield of other varieties on the same and adjoining farms for the years from 1903 to 1905 was 60 bushels, and the average yield for the State of New York for the period from 1903 to 1908 was 32.6 bushels. Mr. Smith comments on his results as follows:

(1903.) A month of very hot, dry weather retarded a good start. One marked feature of the oat is its uniform berry.

(1904.) Our men thought more seed sown would have increased the crop to 90 bushels per acre (2 bushels per acre were sown). Potatoes were grown on the land the previous year. The soil was fairly fertile.

(1905.) The oats were grown on land that had not been clovered or fertilized for 10 years, and wet weather made a lumpy seed bed. On another farm this oat outyielded two other kinds 20 bushels per acre.

(1907.) Have discontinued growing the Sixty-Day oat. It is too light and the color is not satisfactory. The Swedish Select forwarded to us by you in 1903 is an ideal oat in every way. Can not grow enough to supply our seed trade.

(1908.) It has produced fine crops and the very best farmers have continued growing this variety. It is well adapted to clay soil. Last year our sales were about 4,000 bushels, and we could have sold many carloads at good prices if we had had the supply.

WISCONSIN.

As already mentioned, the most extensive series of tests of the Swedish Select oat by farmers was made in Wisconsin. These tests were rendered all the more thorough and accurate through the important part taken by members of the Wisconsin Agricultural Experiment Association. There are now in this office reports on this oat for both 1904 and 1905 from more than two hundred cooperators in Wisconsin. A number of these have sent reports for other years also. Very brief extracts are here reproduced from some of the most instructive of these reports.

Mr. A. D. Larson, of Waupaca, Wis.:

(1904.) The Swedish Select proves to be very well adapted to our soil and climate. It is by far the best yielder and of good quality. Yield per acre, 57 bushels. American Banner, 40 bushels.

(1905.) The soil on which I sowed the oats has been cropped continuously for 12 years without any fertilizer or clover seeding, yet the Swedish Select did very well. Yield per acre, 28 bushels. Average yield of other varieties, 20 bushels.

Mr. Joseph Reich, of East Gibson, Wis.:

(1904.) The oats ripened earlier than other oats of this vicinity, which had some smut and were more affected by the rust in general. Yield per acre, 86 bushels. Quality of grain, extra good. Average yield per acre of other kinds in the same locality, 50 to 60 bushels.

(1905.) I must say that this oat has a tendency to lodge in our locality. I would have thrashed at least 75 bushels if none had lodged, but I had to cut about half of it for hay. It ripens a week or 10 days earlier than our other varieties. Yield per acre, 55 bushels. Quality of grain, extra good. Average yield of other kinds in same locality, 35 to 40 bushels.

Mr. H. W. Kent, of Rusk, Wis.:

(1904.) The oats were cut a little green because of the rust and lodging. This variety does better than other varieties grown here. Yield per acre, 45 bushels. Quality of grain, average. Average yield per acre of other kinds in same locality, 40 bushels.

(1905.) This oat does better on light soil than on heavy. Yield per acre, 40 bushels. Quality of grain, good. Average yield of other kinds in the same locality, 30 bushels.

Mr. J. W. Stevenson, of Rice Lake, Wis.:

(1904.) I consider it a very good variety for this locality, being a good yielder and standing up well. Yield per acre, 50 bushels. Average yield of other kinds, 45 bushels.

(1905.) The Swedish Select for the last 3 years has yielded about 10 bushels more per acre than other varieties I have grown, and I think it is superior for feeding purposes. Yield of other varieties in same locality, 25 bushels.

Mr. A. C. Hagastad, of Etrick, Wis.:

(1904.) The ground was a mixed clover and timothy sod, and one of the lowest and worst fields we have for lodging. When the crop was 4 to 6 inches high we had about one week of cold, rainy weather, which set it back for a long time. It ripened several days ahead of our Siberian oat. It is a heavy yielder, the kernels are large and plump. Will sow all Swedish Select next year. Yield per acre, 70 bushels. Quality of grain, No. 1. Average yield of other kinds in same locality, 60 bushels.

(1905.) The straw is heavy and stiff, so will not lodge easily on rich soil. On lighter soil the straw is not so large but heads out good. Yield per acre, 66 bushels. Quality of grain, No. 1. Average yield of other kinds, 50 to 60 bushels.

Mr. Clarence Jordalen, of Stoughton, Wis.:

(1904.) Am very well pleased with the Swedish Select oat. I like it because it is a greater yielder than the other oats I have raised. It has a very stiff straw and will not lodge very quickly. Yield per acre, 60 bushels. Quality of grain, fairly good. Average yield of other kinds in same locality, 35 bushels.

(1905.) The variety seems to be adapted to this part of the country, for all who try it meet with success and grow no other kinds. Yield per acre, 62 bushels. Quality of grain, exceedingly good; plump and heavy. Average yield of other varieties in same locality, 30 bushels.

Mr. John E. Charley, of Ellsworth, Wis.:

(1904.) I am sorry to say that this oat is not liked here. I had it two years, but did not sell one bit of it for seed. The straw is too coarse and the hull is too thick. We have had the Lincoln and Silver Mine.

Mr. P. J. Bonzelet, of Eden, Wis.:

(1905.) This is the best oat, all things considered, that I have ever seen. Yield per acre, 60 bushels. Quality of grain, good. Average yield of other varieties, 35 to 40 bushels.

Mr. Edward Martin, jr., of De Pere, Wis.:

(1904.) This oat is of the finest quality I have ever seen. It will weigh about 40 pounds to the bushel. When I seeded last spring it averaged 108 pounds to the sack.

Mr. F. H. Williams, of Whitewater, Wis.:

(1905.) I am not at all pleased with the Swedish Select oat. Have tried it 2 years with about the same result. It does not yield good, crinkles down as soon as it begins to ripen, and has a very thick hull. One of my neighbors had 20 acres on good prairie soil that only yielded about 30 bushels per acre. Another got a yield of 23 bushels per acre. Yield per acre, 25 bushels. Quality of grain, good; very thick hull. Yield per acre of American Banner, same locality, 40 bushels.

Mr. J. W. Raven, of Bloomer, Wis.:

(1904.) Those that see the oats want seed. It is the best we have ever raised. A common grain sack holds 105 to 120 pounds. Will have seed grown from 100 acres to sell next year. Yield per acre, 40 bushels. Quality of grain, No. 1. Average yield of other varieties, 35 bushels.

Mr. John Patterson, of Cumberland, Wis.:

(1904.) I have grown this oat for 2 years and will say that while the yield is very good the quality is extra good and it ripens from 10 days to 2 weeks before any other variety and about 4 weeks before the side oats, which is the latest kind we have here. All the Swedish Select I grew last year I sold for seed, and what I have grown this year will be sold for seed. Yield per acre, 68 bushels. Average yield of other varieties on same farm, 55 bushels.

Mr. H. S. Pomroy, of Edgerton, Wis.:

(1904.) I did not keep a record of this variety, but found it not nearly as good as common white oats grown next to it under the same conditions. I shall not try it next season.

Mr. C. A. Peterson, of Cambridge, Wis.:

(1904.) The Swedish Select is superior to other varieties in even stand, earliness, heavy kernel, and trueness to type. Yield per acre, 58 bushels. Quality good. Average yield of other varieties, 26 to 30 bushels.

Mr. H. R. Moldenhauer, of Lebanon, Wis.:

(1904.) The Swedish Select is the best oat ever raised in this country. All other varieties had very much rust, this oat not enough to mention. The berry is plump, and the yield is more than double that of other crops. Yield per acre, 75 bushels. Quality very good. Average yield of other varieties, 30 bushels, and poor at that.

Mr. A. J. Moe, of Midway, Wis.:

(1904.) The variety is a fair yielder, stands up well, weighs heavy, and ripens about 2 weeks earlier than other kinds. Yield per acre, 40 bushels. Quality, fine and plump. Average yield of other kinds, 25 to 30 bushels.

Mr. Reuben Holmgreen, of Black River Falls, Wis.:

(1904.) My Swedish Select was the best of three kinds. Yield per acre, 70 bushels. Quality of grain, No. 1. Average yield of other varieties in same locality, 40 bushels.

Mr. W. S. Hood, jr., of Franksville, Wis.:

(1904.) People who saw the Swedish Select claim it was as nice an oat as they had ever seen and wished me to save seed for them. The kernel has a large meat and thin shuck. Yield per acre, 50 bushels. Quality of grain good. Yield per acre of Silver Mine oat, 40 bushels.

Mr. H. D. Griswold, of West Salem, Wis.:

(1904.) Other oats adjoining the Swedish Select on the same farm yielded 48 bushels per acre, while the latter yielded 61 bushels. Many fields of other varieties yielded only 30 bushels.

Mr. G. R. Downer, of Appleton, Wis.:

(1904.) This is the third year I have grown this oat, and I like it better than any I have ever tried. Yield per acre, 63 bushels. Quality good. Average yield of other varieties, 50 bushels.

Mr. John Dougan, of Beaver Dam, Wis.:

(1904.) The only fault I can find with this variety is that the hulls are rather thick and tough. Yield per acre, 50 bushels. Average yield of other varieties, about 40 bushels.

Mr. C. R. Blodgett, of Marshfield, Wis.:

(1904.) The best oat I have ever used in this locality, and I try to get the best. Yield per acre, 96 bushels. Quality good. Average yield of other varieties, 65 bushels.

Mr. J. W. Kaiser, of Foxlake, Wis.:

(1904.) I was very much pleased with this variety. I had 15 acres this year and harvested 700 bushels of the best oats in this part of the country. Other varieties averaged from 15 to 35 bushels per acre.

Some conflict may be noted in these reports in respect to the lodging of the Swedish Select oat. This may be because of local differences in soil conditions or "lay of the land," or more often, perhaps, because of different previous experiences with other varieties. This oat is known to lodge badly on low rich ground. At the same time, some other varieties may lodge worse. There is also a difference in opinion as to the thickness of the hull. This variety is probably not far from the average in this respect, so the hull may appear thick or thin to the grower, depending on the varieties he has formerly grown.

MISCELLANEOUS.

Mr. J. M. Maher, of Fremont, Nebr., writes as follows concerning his crop of 1905:

It was drilled in on April 25 on cornstalk ground that was disked over twice and not plowed, and was harvested July 20, and was stacked and thrashed October 18. It yielded 680 bushels on 10 acres, or 68 bushels per acre. It was well matured when I cut it, but it never broke down like the other kinds of oats I had alongside of it.

At Odebolt, Iowa, in 1904, the yields of ordinary oats were 40 to 45 bushels per acre, while the Swedish Select yielded from 50 to 60 bushels. Mr. J. A. Cranston, of that place, writes as follows:

These oats ripened about 5 days earlier than common oats.

L. and H. Goeppinger grew the Swedish Select variety for 3 years at Boone, Iowa, and in 1906 harvested 789 bushels, making an average yield of 43 bushels per acre, compared with 36 bushels produced by other oats. This is especially good, inasmuch as in recent years there have been wet seasons in that region which are particularly unfavorable to this variety.

Mr. A. W. Edson, of Austin, Minn., writes: "In this vicinity oats had to be planted in soil too wet." Yet, in his second year's trial of the Swedish Select (1906) it yielded 52 bushels per acre, compared with 40 bushels produced by other varieties. In 1907 the yield was 23 bushels per acre, other varieties averaging 18 bushels.

At North Water Gap, Pa., Mr. Luther Michael obtained a yield of 129 bushels per acre with the Swedish Select in 1904. In his report he makes the following statement:

Quality of grain, first class. Average yield per acre of other oats in the same locality, 40 bushels. The Swedish Select made a very rapid growth from the start and ripened 10 days earlier than any other variety in this section sowed at the same time. It is the best oat I ever grew.

Mr. M. B. Smith grew the oat at Belfast, Me., in 1903, and reports as follows:

Sown broadcast and harrowed in (would have done better drilled). Yield per acre, 65 to 70 bushels. Quality of grain, best I ever saw. Yield per acre of other kinds in same locality, 45 to 50 bushels. It was said by farmers who saw it that it was stouter and of better quality than any other grain they had ever seen raised in that country.

INTERESTING INDIVIDUAL TRIAL.

The most interesting case of success with the Swedish Select oat is that of the trial by Mr. David Jones, of Brandon, Wis. In the early spring of 1899 his son, Prof. L. R. Jones, of the University of Vermont, during a brief visit to the United States Department of Agriculture, obtained 36 kernels of this oat from an exhibition sample and sent them to Mr. David Jones. These were planted that same spring, and we have the following account from Prof. L. R. Jones of the behavior of the variety from that time forward:

Each seed was planted by itself, 6 inches apart. Thirty-three of the seeds grew, making a strong stand and yielding 1¾ pounds of grain. The next year, 1900, all of the 1¾ pounds was sown in drills, but no further attention was given it. Unfortunately, the grain was invaded and trampled down in midsummer, and so did not have a chance to develop a full crop. The yield was approximately 1 bushel. The third year, 1901, this bushel was sown broadcast on one-half acre and no special care given to it. The yield was 40 bushels of grain by measure, weighing 40 pounds per measured bushel, producing, therefore, 50 bushels by weight at 32 pounds per bushel.

In 1902 about 5 bushels of this seed were given to each of three other persons. None of their crop was saved as seed and no record is available of their yields. Mr. Jones sowed about 35 bushels on 12 acres. This yielded 900 measured bushels, weighing 40 pounds per bushel, which by weight would amount to 1,125 bushels. The yield was, therefore, 93 bushels per acre by weight. All of this crop was saved for seed.

In the fifth year, 1903, about 750 bushels of Mr. David Jones's crop were used by him or sold in his immediate neighborhood for seed. The only exact available record for the season is that Mr. F. E. Jones sowed 20 bushels on 10 acres and obtained a crop of 780 bushels by measure, weighing 40 pounds per measured bushel, making, therefore, a yield by weight of 975 bushels, or at the rate of 97.5 bushels per acre. It would be a safe estimate to say that 20,000 bushels were produced from this seed in 1903.

Mr. David Jones has taken much interest in work of this kind, which has not only been of much public benefit, but has always resulted very profitably to himself because of his careful selection of seed and the manner in which the crop has been handled. He has done similar thorough work with other varieties of oats, one of which, the Sixty-Day, was also introduced by this Department.

RECENT REPORTS.

Many of the preceding reports were written several years ago. The following reports are more recent and give a good idea of present conditions in Wisconsin with respect to this oat.

Mr. H. F. Kramer, of Bloomer, Chippewa County, Wis.:

It gives me pleasure to testify to the merits of Swedish Select oats, which I have grown for the past 6 years, for they have surpassed any of the other varieties tried in this locality in appearance, weight, large, plump kernels, early maturity, and a strong straw. While attending the short course in agriculture during the winter of 1902, I saw these oats for the first time. They appeared to be so much better than any others that I determined to secure some for seed, and was one of the first to apply when Professor Moore offered them to the experiment association for trial. The plat of ground on which they were sown was a good fertile soil, and the growing oats had a thrifty and healthy appearance all summer. When ready to harvest the oats averaged about 5 feet in height. The 80 pounds of seed which I had secured yielded 56 measured bushels, or 70 by weight. The season of 1903 was an unfavorable one to the growth of oats, but they led all others that I noticed. Even this last summer of 1907, the poorest in years, the Swedish oats are ahead at least 5 bushels per acre, and in quality also. One more feature, they are practically free from smut and very easily kept so. I have tried both broadcast seeder and the drill with 2½ bushels to 3½ bushels per acre, but find that 3 bushels sown with a drill produces the best results. I have had a ready sale for all that I have grown, in fact, never had enough to fill all of the orders I receive for seed. After shipping seed to various parts of the country, both by carload and in small lots, I have yet to hear the first complaint. To sum it all up, they do well and take wherever tried.

Mr. Fred G. Stroup, of Fond du Lac, Fond du Lac County, Wis.:

The land on which the oats were sown was black prairie soil which sloped to the west with good natural drainage. The land had had corn on it the year before. From the 4 acres we thrashed 180 bushels, machine measure, or 45 bushels per acre. The other oats that we raised that year in the same field, following the same crop, yielded 52 bushels, machine measure, but were sown 2 bushels per acre, while the Swedish

Select were sown 1 bushel per acre. We consider that the Swedish Select oats did considerably the best and have grown them exclusively during the past 3 years. We have had them yield as high as 75 bushels per acre by weight. We have sold this variety quite extensively for seed to farmers living in our neighborhood, and there is not a single case where it did not do better than the other varieties. The neighboring farmers have been loud in their praise of the Swedish Select oats.

Mr. H. E. Rosenow, of Oconomowoc, Waukesha County, Wis.:

We have been growing the Swedish Select oats for the past 4 years with satisfactory results as compared with other varieties, although we have at no time had an extra heavy crop. Comparing the yield with a variety of yellow oat grown for several years past, we have found the Swedish to yield a few bushels more per acre when grown in the same field; both varieties seemed to be affected about equally with rust, and during the past 3 years the rust has no doubt lowered the yield considerably. The Swedish oats also lodged quite badly nearly every year, but all other grain also went down, and thus it can not be said that some other variety has a stiffer straw, as they all seemed to be treated alike during some of our heavy storms, but I believe if the Swedish is given a fair chance it will stand up with any other variety grown. It has a somewhat coarser straw than some smaller varieties of yellow oats grown about here, and the kernel is also larger, but in comparing the inside of the kernel it will hold its own with any variety regardless of color, as the hull is very thin, thus increasing the feeding value considerably.

The demand for pure seed from this variety has been exceptionally good during the past few years, and we have always sold all we had to offer for seed at a fair price and have not only sold to growers in the neighborhood, but have shipped a considerable quantity to other farmers, as well as carloads to seed houses. It is just as easy to grow pure seed of any variety, and there is certainly more profit and pleasure connected with it.

Mr. Charles H. Howitt, of Randolph, Dodge County, Wis.:

We have been growing the Swedish oats for the past 4 years. In the spring of 1904 I secured 1½ bushels of seed from L. L. Olds Seed Company. This was sown on three-fourths of an acre of ground alongside of our common variety. The soil was of a heavy clay nature. There was a difference to be seen all through the growing season, the Swedish being of a darker green color and seemed to make a heavier growth. About 10 days before ripening they lodged quite badly on account of a storm, and accordingly the grain that we thrashed was rather light weight. The yield was at the rate of 50 bushels per acre.

The following spring we sowed 8 acres of the Swedish and 6 acres of our common variety in separate fields on the same kind of soil and both following a crop of barley. The Swedish yielded a trifle over 50 bushels per acre and the common variety 40 bushels per acre, a difference of 10 bushels in favor of the Swedish oats. The past 2 years we have grown the Swedish oats entirely for our main crop, with very satisfactory results.

The Swedish oats are now grown quite extensively in our neighborhood, and from what I have been able to learn from those who have grown them they seem to be the best adapted to a well-drained heavy soil.

QUALITY OF THE KERNEL IN THE SWEDISH SELECT OAT.

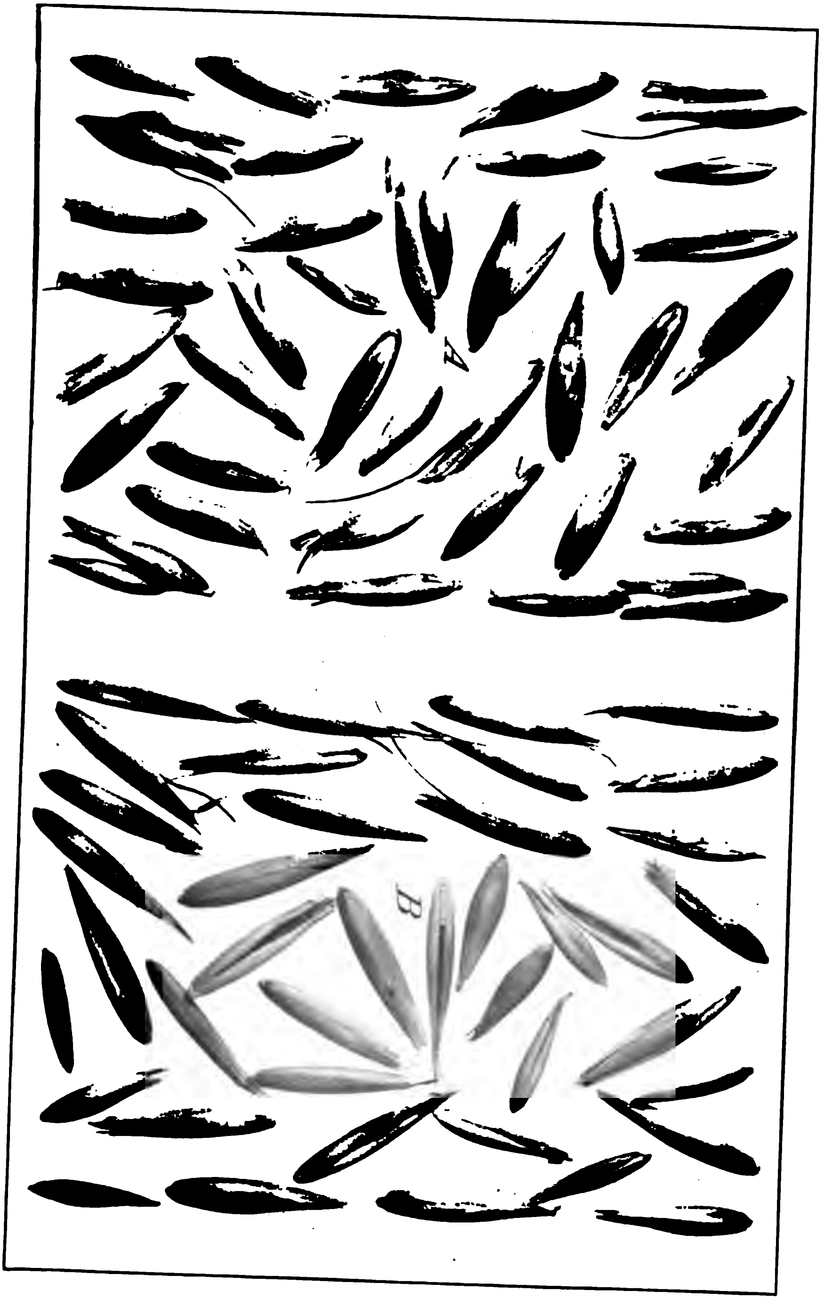
Soon after the introduction of the Swedish Select oat, many Wisconsin farmers remarked on the quality of the kernel, mentioned the thinness of the hull, and considered it to be in several respects an improvement over other kinds. (Pl. IV.) Our own investigations later have shown that several other varieties exceed the Swedish Select both in weight per bushel and proportion of meat to hull, but a larger number of varieties are inferior to it in these characteristics, and particularly so in the case of Wisconsin oats. Compared with the more commonly grown varieties, therefore, it remains true that this kernel stands rather high in quality in the chief oat districts of the United States.

The following interesting determinations were furnished by Mr. C. W. Warburton, now in charge of oat investigations of the Bureau of Plant Industry. The weight per bushel, the weight of 1,000 kernels, and the percentage of meat in the kernel were determined in samples of a number of different oat varieties grown in Wisconsin, Kansas, North Dakota, and Montana, with results as given in the following table:

TABLE VII.—*Weight per bushel, weight of 1,000 grains, and percentage of kernel to whole grain in a number of different oat varieties grown in several States.*

WISCONSIN.

	1905.	1906.	1907.	Average.
Kherson.				
Weight per bushel (pounds)	35.50	33.75	25.25	31.50
Weight of 1,000 grains (grams)	22.19	18.75	12.68	17.87
Percentage of meat in kernel	78.07	70.08	65.65	71.27
Sixty-Day.				
Weight per bushel (pounds)	30.50	29.25	26.25	28.67
Weight of 1,000 grains (grams)	18.85	16.88	13.97	16.57
Percentage of meat in kernel	72.60	73.74	66.45	70.93
Swedish Select.				
Weight per bushel (pounds)	34.00	36.50	27.50	32.67
Weight of 1,000 grains (grams)	24.25	29.71	23.84	25.93
Percentage of meat in kernel	70.09	69.63	67.44	69.05
White Bedford.				
Weight per bushel (pounds)	35.50	....	24.50	30.00
Weight of 1,000 grains (grams)	21.65	....	17.70	19.67
Percentage of meat in kernel	73.42	....	65.83	69.62
White Tartar.				
Weight per bushel (pounds)	32.50	....	27.00	29.75
Weight of 1,000 grains (grams)	19.84	....	19.38	19.61
Percentage of meat in kernel	69.13	....	69.86	69.49
Belyak.				
Weight per bushel (pounds)	35.50	....	26.00	30.75
Weight of 1,000 grains (grams)	25.98	....	17.41	21.69
Percentage of meat in kernel	70.35	....	67.38	68.86
Wisconsin Wonder.				
Weight per bushel (pounds)	33.50	....	23.00	28.25
Weight of 1,000 grains (grams)	23.73	....	17.33	20.53
Percentage of meat in kernel	70.16	....	63.71	66.93
Golden Fleece.				
Weight per bushel (pounds)	....	29.50	22.25	26.00
Weight of 1,000 grains (grams)	....	19.28	15.47	17.37
Percentage of meat in kernel	....	57.55	66.17	61.86
N. K. & Co. White.				
Weight per bushel (pounds)	....	23.75	19.75	21.75
Weight of 1,000 grains (grams)	....	22.78	15.74	19.26
Percentage of meat in kernel	....	54.86	59.61	57.24



KERNELS OF SWEDISH SELECT (*A*) AND LINCOLN (*B*) OATS.

(About one and one-half times natural size.)

TABLE VII.—*Weight per bushel, weight of 1,000 grains, and percentage of kernel to whole grain in a number of different oat varieties grown in several States*—Continued.

MONTANA.[a]

	1906.	1907.	Average.
Sixty-Day.			
Weight per bushel (pounds)	39.00	35.75	37.37
Weight of 1,000 grains (grams)	24.44	22.64	23.54
Percentage of meat in kernel	77.64	76.05	76.84
Swedish Select.			
Weight per bushel (pounds)	40.25	38.75	39.50
Weight of 1,000 grains (grams)	32.89	29.82	31.35
Percentage of meat in kernel	77.69	71.40	74.54
Salzer's Big Four.			
Weight per bushel (pounds)	40.25	41.00	40.62
Weight of 1,000 grains (grams)	28.54	29.06	28.80
Percentage of meat in kernel	76.30	70.75	73.52
Siberian.			
Weight per bushel (pounds)	42.00	41.25	41.62
Weight of 1,000 grains (grams)	32.99	33.86	33.42
Percentage of meat in kernel	70.99	75.46	73.22
Clydesdale.			
Weight per bushel (pounds)	40.25	41.00	40.62
Weight of 1,000 grains (grams)	31.72	30.59	31.15
Percentage of meat in kernel	75.28	69.36	72.32
Progress.			
Weight per bushel (pounds)	41.50	40.75	41.12
Weight of 1,000 grains (grams)	30.52	29.78	30.15
Percentage of meat in kernel	72.35	72.29	72.32

[a] All samples of grain from Montana contained a considerable percentage of hulled kernels; hence, the weight per bushel is somewhat higher than the grain itself justifies.

NORTH DAKOTA.

	1906.	1907.	Average.
Sixty-Day.			
Weight per bushel (pounds)	38.25	35.75	37.00
Weight of 1,000 grains (grams)	19.44	22.22	20.83
Percentage of meat in kernel	75.29	75.81	75.55
Seventyfive-Day.			
Weight per bushel (pounds)	....	36.00	....
Weight of 1,000 grains (grams)	....	24.01	....
Percentage of meat in kernel	....	73.45	....
Swedish Select.			
Weight per bushel (pounds)	37.50	34.00	35.75
Weight of 1,000 grains (grams)	30.14	28.84	29.49
Percentage of meat in kernel	69.49	70.78	70.23
Tartarian.			
Weight per bushel (pounds)	....	31.00	....
Weight of 1,000 grains (grams)	....	23.08	....
Percentage of meat in kernel	....	68.15	....
Belyak.			
Weight per bushel (pounds)	....	31.75	....
Weight of 1,000 grains (grams)	....	26.48	....
Percentage of meat in kernel	....	67.58	....
North Finnish Black.			
Weight per bushel (pounds)	....	30.00	....
Weight of 1,000 grains (grams)	....	21.19	....
Percentage of meat in kernel	....	66.40	....

KANSAS, 1907.

	Weight per bushel.	Weight of 1,000 grains.	Meat in kernel.
	Pounds.	*Grams.*	*Per cent.*
Sixty-Day	34.50	20.27	75.85
Early Champion	29.25	17.44	74.32
White Russian	27.25	20.31	72.63
Kherson	26.50	17.46	72.45
Swedish Select	38.75	32.01	72.19
Red Rustproof	27.75	25.75	70.54
Stavropol	25.25	17.33	69.92
Silver Mine	26.25	21.79	68.62
Minnesota, No. 202	25.25	19.34	67.87
Canadian	28.50	21.85	60.84

The percentage of meat in the kernel was determined by hulling 100 kernels taken at random from a fair sample, weighing the hulls and inside portions separately, and then calculating the percentage of the latter weight to the combined weight. An average of three such determinations for each sample gave the result that is set down for each variety each year.

The largest amount of data was obtained from Wisconsin material. Of the varieties examined from that State, the Swedish Select stands much the highest in weight per bushel in an average of samples from 3 years' crops, the average weight for this oat being 32.67 pounds. Only one other variety, the Kherson, reached even 31 pounds. In weight of 1,000 kernels in grams the Swedish Select also exceeds any of the others. This quality, however, is not important. In percentage of meat in the kernel this variety falls considerably below those having the highest percentages, ranking only fifth in this respect. The Kherson and the Sixty-Day are considerably higher, while the White Bedford and the White Tartar are also somewhat higher.

Average determinations of Montana samples out of two years' crops show the Swedish Select to be inferior in weight per bushel to four others in a comparison with five varieties. In weight of 1,000 kernels it stands second in rank, and, what is more important, is second also in percentage of meat in the kernel.

In the case of the North Dakota varieties there are averages of 2 years' samples in only two instances, those of the Sixty-Day and the Swedish Select, the latter exceeding the former in both weight per bushel and weight of 1,000 kernels, but falling considerably below it in percentage of meat in the kernel. For the 1907 crop only, the Swedish Select is exceeded by the Seventyfive-Day oat in both weight per bushel and percentage of meat, but exceeds the latter in weight of 1,000 kernels, and exceeds all the three remaining varieties in all these qualities.

Kansas samples were examined from only one year's crop, that of 1907. Compared with nine other kinds, the Swedish Select ranks fifth in percentage of meat, falling considerably below the Sixty-Day in this quality, but exceeds all other varieties in both weight per bushel and weight of 1,000 kernels.

A series of tests similar to the above was made by Shepperd and Churchill with a considerable number of varieties at the North Dakota Agricultural Experiment Station, samples being taken from the crops of 1904, 1905, and 1906.[a]

The results of these tests show that the Swedish Select stands considerably above the average of oat varieties in percentage of meat in the kernel, but considerably below the best in this respect, the Sixty-Day and the Tartarian being usually the best. In average weight per bushel it was good and stood rather high in weight of 1,000 kernels.

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[a] Bulletin 75, North Dakota Agricultural Experiment Station, February, 1907, pp. 317–322.

On the whole, the tests just mentioned indicate that the Swedish Select oat is usually high in weight per bushel and very high in absolute weight of kernels. At the same time, the percentage of meat in the kernel is found to be higher than might be expected, always above the average, and sometimes unusually high. The combination of these qualities therefore indicates that the feeding value from these standpoints is much above the average.

CHEMICAL ANALYSES.

For comparison, many chemical analyses of this oat and of others have been made by Dr. J. S. Chamberlain, formerly of the Bureau of Chemistry of this Department, in connection with laboratory work in cooperation with this Bureau. These analyses[a] show no extreme quality in the Swedish Select, but indicate that it is a variety of good feeding value, possessing a protein content above the average and a narrow nutritive ratio; that is, the ratio of protein to carbohydrates and fats is rather high. There is an unusually important feature of these analyses, however, in the fact that the average results with 128 samples of domestic-grown Swedish Select oats show a considerable increase in protein content over the original introduced seed. This is very gratifying, in view of the claim sometimes made that introduced crops, although an improvement at first, tend to deteriorate afterwards.

VALUE OF THE INTRODUCTION.

As previously mentioned, the Swedish Select oat has received the greatest attention in Wisconisn, though also grown to a large extent in South Dakota and Montana. It has been shown that the 10-year average yield of this oat at the Wisconsin Agricultural Experiment Station was 8½ bushels greater than the average of all other varieties. Also, calculating the averages of the highest yielding varieties for several different periods, in which all varieties were grown every year, there is a constant difference in yield of about 12 bushels per acre in favor of the Swedish Select in comparison with the next highest variety. Taking the mean of these two determinations, or, rather, reducing the latter one (for it is the most accurate), we can probably safely assume a constant average increase in yield of at least 10 bushels per acre for the Swedish Select over that of other varieties in these tests.

As all varieties were grown under the same conditions it is reasonable to infer that the Swedish Select oat will show the same superiority over ordinary kinds when grown throughout the State. It will therefore be interesting to calculate the possible increase in oat production in Wisconsin if this oat were grown exclusively. The average oat acreage of Wisconsin has recently been about 2,400,000 acres, and the average production about 80,300,000 bushels. The proportion of this production that is already Swedish Select is 30,000,000 bushels, or nearly three-eighths of the crop. With the same yield per acre, this portion would be grown on nearly three-eighths of the acreage, but of course it is really less. For safety in calculation we will assume it to be just three-eighths. Then there remains five-eighths of the acreage, or about 1,500,000 acres, now sown to other varieties. Ten bushels on each of these acres, or in all 15,000,000 bushels at least, would therefore be added to the present oat production of Wisconsin if Swedish Select oats were grown exclusively.

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[a] See "The Feeding Value of Cereals," Bulletin 120, Bureau of Chemistry, U. S. Dept. of Agriculture, 1909, pp. 18–25.

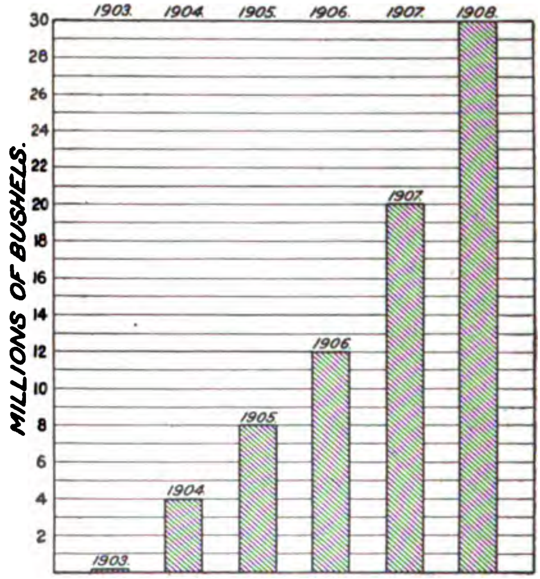

FIG. 3.—Diagram showing in millions of bushels the rapid increase in the production of Swedish Select oats in Wisconsin from 1903 to 1908.

Now, what is the actual present increase in production in Wisconsin due to the use of this oat? As stated, the present Swedish Select acreage is less than three-eighths of the total. Again, for safety in calculation we may assume it to be at this time at least one-fourth, or 600,000 acres. Ten bushels increase on each of these acres, or, 6,000,000 bushels in all, is therefore the present annual addition to the oat production of Wisconsin that can conservatively be credited to the use of the Swedish Select. The value of this increase in production at 36 cents per bushel, the average farm price December 1 for the years 1904–1908, is $2,160,000. The average farm price for 1907, 1908, and 1909, however, was 44 cents per bushel, which would increase the value to $2,640,000. Add to this the facts that the 6-million-bushel increase is reckoned up to 1908 only and that this extra production no doubt continues to be somewhat greater each year, and it is seen that the present increase in farm value is probably not far from $3,000,000 annually, and certainly over $2,500,000, but the more conservative figures will be used.

The estimated production of the Swedish Select oat in Wisconsin ranges from 150,000 bushels in 1903 to 30,000,000 bushels in 1908. This rapid increase is shown graphically in figure 3. Figure 4 shows the average farm value of the entire oat crop of Wisconsin, that of the Swedish Select oat alone, and the increase in farm value of the entire crop due to the use of the Swedish Select variety.

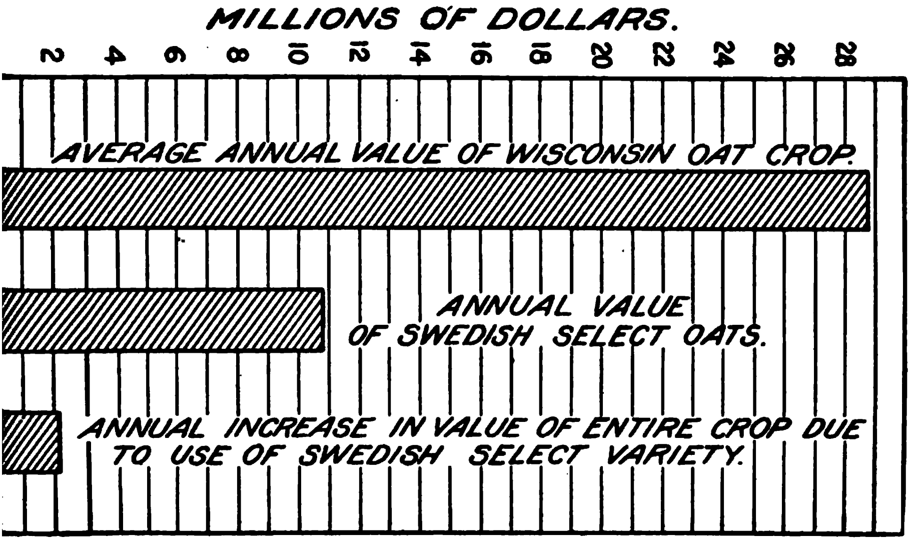

FIG. 4.—Diagram showing in millions of dollars the average farm value of the entire oat crop in Wisconsin, that of the Swedish Select oat, and the annual increase in the farm value of the entire crop due to the use of the Swedish Select variety.

Outside of the State of Wisconsin the present production of the Swedish Select oat is more difficult to estimate, but, as already stated in the introduction, the entire production in the United States is surely 50,000,000 bushels annually. Using this figure, the present farm value of the Swedish Select oat at the average farm price per bushel for the years 1904–1908 is at least $18,350,000 annually.

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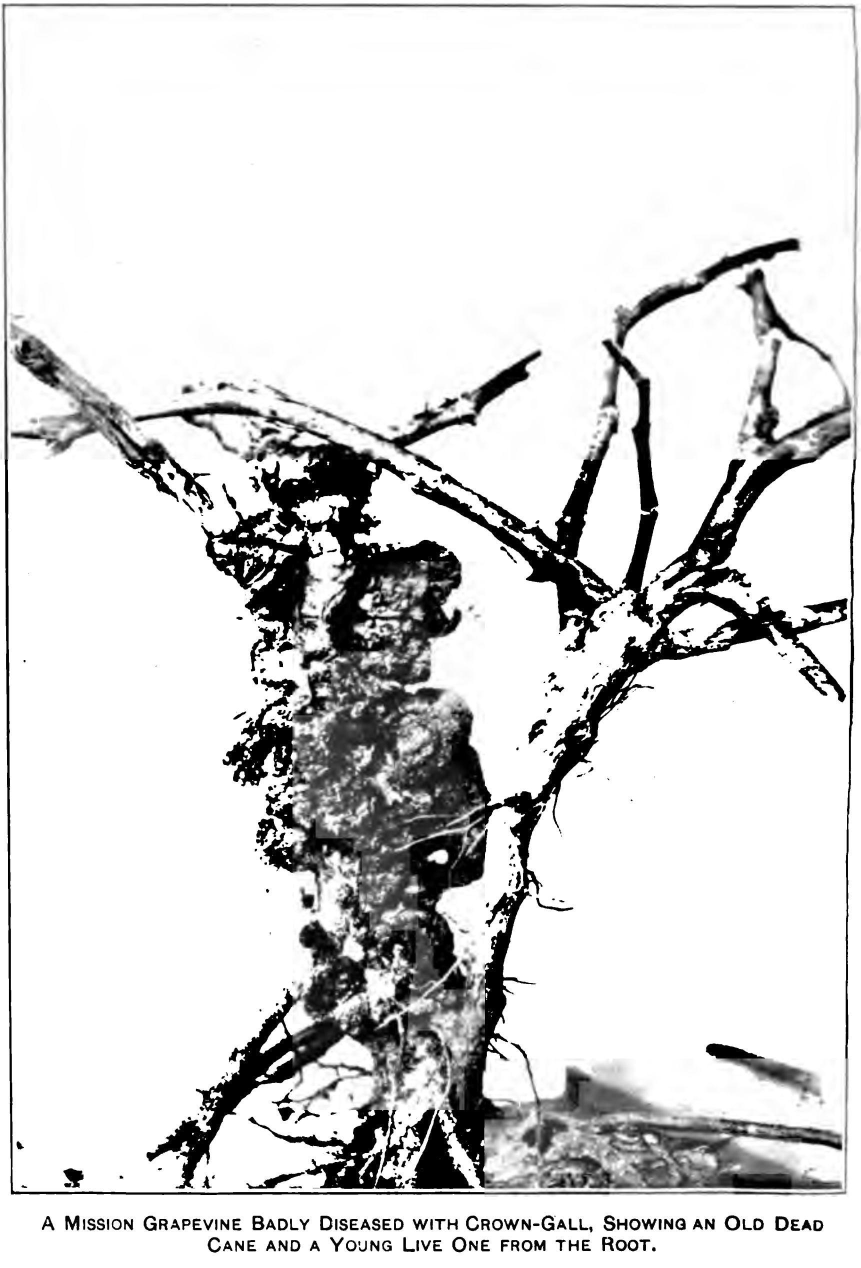

A MISSION GRAPEVINE BADLY DISEASED WITH CROWN-GALL, SHOWING AN OLD DEAD CANE AND A YOUNG LIVE ONE FROM THE ROOT.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 183.
B. T. GALLOWAY, *Chief of Bureau.*

FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

BY

GEORGE G. HEDGCOCK,
PATHOLOGIST, FRUIT-DISEASE INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 11, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Field Studies of the Crown-Gall of the Grape," by Dr. George Grant Hedgcock, Pathologist, Investigations in Forest Pathology.

The paper embodies the results of several years of investigation of the crown-gall of the grape in the western United States, especially of the susceptibility and immunity to the disease of a number of the most important varieties of grapes. It is found that a few varieties are resistant to the crown-gall, and that the use of the varieties Rupestris St. George and Lenoir as stocks for engrafting congenial nonresistant varieties affords a ready means of successfully overcoming the effects of the disease under soil and climatic conditions favorable to such varieties.

Studies on the congeniality of *Vitis vinifera* to resistant stock varieties, and the adaptation of varieties to soil, climatic, and other conditions, are discussed by Prof. George C. Husmann in Bulletin 172 of this Bureau.

The writer of this paper is indebted to Prof. Fabian Garcia, of the Agricultural Experiment Station of New Mexico, for hearty cooperation in obtaining information as to the extent of crown-gall in that Territory.

This paper completes the work of Doctor Hedgcock on the subject, but studies of the field end of this disease will be continued by the Office of Fruit-Disease Investigations of this Bureau.

I recommend that this paper be published as Bulletin No. 183 of the special series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

INTRODUCTION.

A disease of grapevines, under the various names of "black-knot," "crown-knot," "root-knot," "crown-gall," and "root tumors," has been known in the United States for many years. As early as 1880 it had become common in California (61)[a] and often resulted in serious injury to the vineyards. With the introduction of European vines into new localities the disease has become widespread.

During 1903 Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, found that a disease was killing the grapevines at Bernalillo, N. Mex. The station having no plant pathologist the Bureau of Plant Industry was requested to make an investigation of the epidemic, and the task was assigned to the writer.

A preliminary examination of the vines revealed the presence of galls in large numbers on the canes and roots of many of them. Experiments were at once undertaken for the control of the disease and the cure of the diseased vines. After a thorough test of ordinary remedies with little or no results, an experiment was conducted to find varieties resistant to the disease.

Meanwhile studies were made of the cause, nature, communicability, and effect of the disease. This involved a number of species and varieties of grapes and a series of experiments in the greenhouse and gardens at St. Louis, Mo., and later at Washington, D. C.

This bulletin outlines the history of the disease and gives the results of these studies and experiments, which are of a preliminary nature, but are of great importance, especially to growers of grapes in Texas, New Mexico, Arizona, and California. Certain varieties of grapes are found to be so susceptible to crown-gall as to be unprofitable for vineyards in many localities, while others are resistant to a considerable degree and are recommended for planting. Methods for the prevention and control of the disease are outlined.

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[a] The serial numbers in parentheses used in this paper refer to the bibliography which will be found on pages 31 to 33.

The crown-gall or a similar disease is thus reported on grapevines in Europe from Germany, France, Italy, Denmark, and England; in North America, from the United States, Canada, and Mexico; in Australia, from New South Wales; and in Africa, from Cape Colony.

In the United States the disease occurs in nearly every locality where varieties of *Vitis vinifera* are grown. It occurs on some American varieties in Canada and various portions of the United States. The author has observed the disease in localities in the following States and Territories: Washington, Oregon, California, Arizona, New Mexico, Colorado, Texas, Arkansas, Nebraska, Missouri, and Iowa.

DISTRIBUTION OF THE DISEASE ON SPECIES AND VARIETIES OF GRAPES.

In the United States, as well as in foreign countries, the varieties most susceptible to the disease belong to the species *Vitis vinifera*. There are a few exceptions to this rule, especially in the northern United States (41) and Canada (20), where varieties, hybrids or crosses, of *Vitis labrusca*, Champion, Salem, and others are attacked by the form of the disease on the canes. Varieties of *Vitis linsecomii* and *Vitis aestivalis* are occasionally diseased on both canes and roots. Varieties of *Vitis rupestris* are rarely attacked by either of the forms of the disease and appear to be nearly immune. Data will be given later in this bulletin on the resistance of individual varieties of several species.

DISTRIBUTION OF THE DISEASE ON YOUNG AND OLD VINES.

The disease has been found to a limited extent on the roots of yearling vines of *Vitis vinifera* in vineyards and nurseries in Texas, Arizona, New Mexico, California, Oregon, and Washington. It is most common on the roots and canes of older vines, increasing in extent as the vines grow older. The oldest vineyards usually contain the highest percentage of diseased vines.

IMPORTANCE OF THE DISEASE.

In Germany, France, and Italy earlier writers report whole vineyards destroyed by the crown-gall. Later writers minimize the importance of the disease. This decrease of disease is no doubt due largely to the use of American varieties of grapes and their hybrids for ingrafting with varieties of *Vitis vinifera* in the replanting of vineyards destroyed by the phylloxera. It may also be due to the gradual selection of the more resistant European varieties by growers of grapes. Our observations and experiments sustain such a conclusion, since American varieties are more resistant to the crown-gall and a great variation of susceptibility is shown by European varieties.

In Cape Colony, as well as in the United States, certain varieties are subject to the crown-gall, such as the Muscat of Alexandria (Hanepoot). Mr. C. P. Lounsbury reports, by letter, that as much as 70 per cent was found diseased in a vineyard six or seven years old planted with Hanepoot (Muscat of Alexandria) vines. In vineyards in Texas, New Mexico, and Arizona all the vines of this variety and of the Mission variety are often diseased, and many of them are dead at the end of four years. In one vineyard at Bernalillo, N. Mex., 3,000 Mission vines died from the disease in four years from the time the vineyard was planted. The loss from the ravages of the disease is a large and important item in many localities, especially in this section, amounting to many thousands of vines.

If we consider the northern form of disease known as necrosis (41) or black-knot (22) as identical with crown-gall, the importance of the disease is greatly increased. Until it has been definitely proved that this form of disease is due to a different organism, owing to the apparent similarity of the black-knot of the Northern States and the cane-gall form of crown-gall in the Southwestern States, the writer will consider these forms of disease identical.

DESCRIPTION OF THE FORMS OF CROWN-GALL.

ROOT GALLS.

The disease is most frequently found in its earlier stages in the form of more or less spherical, fleshy galls, or outgrowths (Pl. III, fig. 2), from the roots of young plants grown from cuttings or at the point of union of scion and root in young grafted vines. These usually originate in a wound. They often become confluent (Pl. II, fig. 1).

These galls at first are white or flesh colored and can not be distinguished from callus, but they usually develop more rapidly. The surface as they grow older is more or less coarsely convoluted. They more frequently occur near the surface of the ground and often attain a diameter of 2 or 3 inches on large vines.

CANE GALLS.

The disease on old vines extends from the crown upward and attacks the older branches of the canes, often to the height of from 3 to 5 feet from the ground. Fleshy excrescences or confluent galls develop usually along lines parallel to the length of the canes (Pl. II, fig. 2). These growths are sometimes continuous for several inches or may develop in bunches. In spring the young galls resemble wound tissue, but later in the season they often assume a dark-brown or black color due to the death and decay of the outer tissues.

OTHER MANIFESTATIONS OF THE DISEASE.

The disease manifests itself in a number of ways in addition to the formation of galls. The affected vines are stunted in their growth. The leaves are usually smaller and are often etiolated or chlorotic. The galls usually die annually, and if under ground they commonly rot away, the decay killing the adjacent tissues of the root and often killing the vine above the point of attack.

DEVELOPMENT OF THE FORMS OF CROWN-GALL.

DEVELOPMENT OF ROOT GALLS.

The subterranean form of the disease usually does not develop abundantly the first year on vines grown from cuttings. An exception must be made where cuttings are taken from diseased vines. In an experiment with cuttings selected from healthy and diseased vines of the same varieties a marked difference was noted in the relative development of the disease. The experiment was conducted as follows:

Cuttings were taken from apparently healthy and from plainly diseased Thompson Seedless, Zabalkanski, Black Malvoisie, and Mission vines from the same vineyards at Bernalillo and Mesilla Park, N. Mex. They were planted in the greenhouse in sterilized soil in sterilized pots[a] and watered with boiled water. The results of the experiment are shown in Table I.

TABLE I.—*Results of an experiment to determine the relative susceptibility to crown-gall of four varieties of grapes grown in New Mexico, cuttings being made from apparently healthy vines and from vines plainly diseased.*

Variety.	Diseased cuttings.			Healthy cuttings.		
	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Thompson Seedless	25	80.0	20.0	33	100.0	0.0
Zabalkanski	4	50.0	50.0	7	100.0	.0
Black Malvoisie	43	60.5	39.5	43	79.0	21.0
Mission	19	68.4	31.6	19	94.7	5.3
	91	67.0	33.0	102	90.2	9.8

It will be seen from the table that the use of cuttings taken from plainly diseased plants increased the development of the crown-gall from 9.8 to 33 per cent, or 23.2 per cent. It is also seen that where cuttings were selected from apparently healthy vines in diseased vineyards some of them (9.8 per cent) became diseased upon rooting. Similar results were obtained by cuttings planted in the soil in a vineyard.

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[a] Sterilized in an autoclave for three hours at a temperature of 110° C. (230° F.).

Nearly all of the galls formed on the vines grown from cuttings in the experiment just mentioned were more or less spherical in shape and developed below the surface of the ground, often on the lower ends of the cuttings.

In structure these root galls are from the first very spongy and watery. They consist at first entirely of parenchymatous tissue. Later there develops in the interior curled and distorted masses of wood cells and vessels, and older galls occasionally become quite woody, especially where they do not die at the end of the growing season.

The gall develops in every instance, where closely observed, either from an injury to the meristem layer beneath the bark of the cuttings or from a cut surface. An outgrowth of cells first takes place directly from the meristem layer, resembling callus. This develops rapidly into a gall.

DEVELOPMENT OF CANE GALLS.

In the cane galls a similar development takes place, but it is not so rapid. Cane galls usually form along a line of injury, often from a wound made in pruning. Very frequently the bark of the canes of grapevines susceptible to frost, such as the Muscat of Alexandria, is ruptured by freezing in the spring after growth has begun. The bark is usually ruptured in longitudinal lines. From the meristem layer in these wounds there develops directly numerous rough galls which are more or less confluent. This gives rise to the form of disease (Pl. II, fig. 2) known in this country as black-knot (22) and in Europe as broussins (42), rogna (23), and Grind (15). These galls often become more or less woody in structure.

The cane galls have been observed as common, with few exceptions, only in localities where vines are subject to frost injury. Where they have been found on vines, all forms of variation have been noted from the spherical root galls of the roots and crowns of the vines to the confluent cane galls on the shoots, indicating that they are both forms of the same disease.

The cane galls usually dry up in autumn, and may break away from the canes the following season, especially when a further development of galls takes place along their margin.

DEVELOPMENT OF THE DISEASE ON SEEDLINGS.

The seedlings used in the experiments described in this bulletin, unless otherwise designated, were grown from seed sterilized in concentrated sulphuric acid for ten minutes, neutralized with a 10 per cent water solution of potassium hydroxid, and then washed in sterile water. These were planted and grown in soil sterilized in an autoclave at a temperature of 110° C. (230° F.), placed either in pots similarly sterilized or in benches constructed of new pine and cypress lumber, and washed on the surface with a 2 per cent water solution of copper sulphate.

Seedlings of the following varieties of grapes were grown under these conditions: Flame Tokay, Muscat of Alexandria, Mission, Malaga, Black Malvoisie, Concord, Delaware, Catawba, and Niagara. All such seedlings remained free from the disease except where they were wounded and inoculated either with pieces of root galls or with cultures of bacteria. The galls on small seedlings develop at a much more rapid rate than the diameter of the canes or roots of the plants on which they occur; for example, on the root of a vine with a diameter of a quarter of an inch a gall developed in two months with a diameter of an inch (Pl. III, fig. 2).

Cane galls did not develop on any of the plants in the experiments, as all inoculations were made on the vines either at or just below the surface of the soil.

DEVELOPMENT OF THE DISEASE IN VINEYARDS.

In vineyards wherever the disease is found in its worst forms the galls are developed on the roots in great numbers by the end of the third year from the time of planting the vines. Beginning about the fourth year there takes place a development of galls on the canes of some of the diseased plants, but on many vines the disease develops only below the surface of the soil.

THE EFFECT OF CROWN-GALL.

The presence of the disease on grapevines becomes apparent within a short time after they are attacked. Usually the leaves lose their healthy dark-green color and become more or less chlorotic, varying with the intensity of the disease. The growth of the canes becomes slower until they die above the point of attack, due to the cancerous effect of the disease.

The galls have a poor epidermal covering, which is constantly being ruptured during their development. This permits the evaporation of the sap of the vines. In the dry climate of the southwestern United States this loss of sap easily becomes a serious matter and quickly results in the lowering of the vitality of the diseased vines.

In New Mexico, Arizona, and western Texas the vines are usually cut back and grown by the stump system (Pl. IV, fig. 2), in order to cover the vines with soil during the winter as a protection against cold. In spite of the fact that the vines are protected, they are injured in the spring by frost after they are uncovered and severely pruned. The bark is often burst by freezing near the surface of the ground, and this enables the disease to easily gain an entrance on the canes. The vine soon dies above the point of attack (Pl. I). New shoots then develop from the canes or roots below the diseased portion, as shown in this illustration. These shoots are never so vigorous as the original ones and have a tendency to sprawl over the ground, it being a difficult matter to establish a new erect stump or vine (Pl. IV, fig. 1). After the vine dies back a couple of times it is usually worthless, although it may remain alive at the roots. This condition frequently obtains at the end of four to five years under conditions favorable to the disease. In California, Oregon, and Arizona it usually requires a longer period. A large number of vineyards in localities in California where vines suffer little from late frost were found almost free from the disease.

THE SUSCEPTIBILITY AND RESISTANCE OF SPECIES AND VARIETIES OF GRAPES TO CROWN-GALL.

Two factors apparently enter into the problem of the resistance and immunity of grapevines to the disease:

(1) The susceptibility of the species or variety to frosts, etc., in the locality where it is grown. This varies not only with the species but also with the variety grown; for example, the Concord, Catawba, Delaware, and other American varieties are perfectly hardy and usually free from the disease in sections where varieties of *Vitis vinifera* are seriously injured by freezing in winter and late frosts in the spring and become badly diseased.

(2) The variation in the chemical constituents of the sap of different varieties of grapes may enter into the problem of resistance. The sap of the vines of some of the resistant varieties is especially acid to the taste, much more so than that of some of the more susceptible varieties. This acidity may increase the resistance. Unfortunately no chemical determination has been made to fully establish this opinion, and it is offered as a working hypothesis for future investigators.

In the Southern and Western States it was found by observation that varieties of *Vitis vinifera* are less resistant than those of *Vitis labrusca* and *V. aestivalis*, although in Arkansas in the Ozark region two species became slightly diseased, one variety of which, Goethe, a hybrid of *Vitis vinifera* and *V. labrusca*, became badly diseased in a number of instances at the age of from 10 to 12 years. Some varieties of *Vitis aestivalis*, such as Herbemont, appear to be immune to the disease.

Vines of *Vitis cordifolia* and *V. linsecomii* purchased from a nursery were found badly diseased with crown-gall, indicating a susceptibility of these species to the disease.

Vines of varieties of *Vitis rupestris* and *V. vulpina*, so far as observed, are apparently quite resistant, in fact almost immune to the disease; for example, Rupestris St. George and Rupestris Martin.

THE SUSCEPTIBILITY OF VARIETIES OF EUROPEAN GRAPES.

All the data collected from experiments and observation indicate that there is a great range of variation in susceptibility of the varieties of any given species to the disease.

Of the varieties diseased to the greatest extent in any given locality it was observed in general that those most easily injured by late spring frosts are most susceptible to the disease. There are probably some exceptions to this rule, since the disease is able to gain an entrance into the tissues of vines through wounds without the action of frost.

The varieties of *Vitis vinifera* that were found in the experiments most susceptible to the disease were the Mission from California, Muscat of Alexandria, Flame Tokay, Rose of Peru, and Malaga varieties. There are no doubt others not included in the experiments that are equally susceptible.

At Bernalillo, N. Mex., an experimental vineyard for the study of the disease has been conducted since 1903. The vineyard originally contained vines of the Mission variety from California, badly diseased with crown-gall at the age of 4 years (Pl. I). These vines were first treated in various ways in an attempt to control the crown-gall, but without success. The diseased vines were then replaced chiefly with other varieties of *Vitis vinifera* in an effort to obtain resistant vines. A number of the best varieties of commercial wine and table grapes grown on their own roots, purchased in California, were set in the holes from which the diseased Mission grapes had been removed (Pl. IV, fig. 1). This put the new vines to an exact and extreme test, since each vine was planted in infected soil.

The vines of some varieties became badly diseased in two years and were replaced at the end of the second year with more resistant varieties. The following table presents the result of the experiment to July 1, 1909:

Table II.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Bernalillo, N. Mex., in infected soil.*

Variety.	Number of vines grown.	Age.	Proportion of diseased plants resulting.	Growth of plants.
		Years.	*Per cent.*	
Rupestris St. George	300	3	1.0	Very good.
Feher Szagos	500	5	5.0	Do.
Sweetwater	400	3	5.4	Do.
Golden Chasselas	500	3	7.2	Uneven.
Seedless Sultana	300	5	8.1	Good.
Carignane	100	3	9.0	Do.
Grenache	200	3	10.0	Do.
Gros Colman	50	5	11.0	Do.
Mataro	300	3	12.0	Do.
Sauvignon Vert	200	3	13.3	Uneven.
Black Malvoisie	500	3	14.0	Good.
Burger	200	3	17.0	Do.
Lenoir	500	5	18.7	Very good.
Zinfandel	200	5	22.3	Good.
Purple Damascus	100	5	24.0	Uneven.
Thompson Seedless	100	5	24.6	Do.
Riesling	300	5	36.0	Good.
Burgundy	300	3	46.0	Uneven.
Malaga	100	5	52.0	Do.
Rose of Peru	50	3	64.0	Do.
Mission (New Mexico)	1,000	5	75.0	Do.
Flame Tokay	300	3	70.0	Do.
Muscat of Alexandria	650	3	72.5	Do.
Mission (California)	300	5	95.0	Do.

It will be seen from the table that the varieties showing the least disease are headed by the hybrid Rupestris St. George, which shows a resistance of 99 per cent. The vines of this variety that were diseased showed only traces of the crown-gall and no effects whatever. Other promising varieties are Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lenoir. The affected vines of these varieties were, as a rule, but slightly diseased, and have shown a good growth.

The most diseased vines, viz, Mission, Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, Thompson Seedless, and Purple Damascus, will not prove profitable in infected soil in conditions similar to those at Bernalillo.

The land upon which these vines were grown is a sandy, alluvial deposit of the Rio Grande River, underlain chiefly by sand and gravel. It was examined by Mr. W. W. Mackie, of the Bureau of Soils, October 22, 1906, and samples were taken for a test for alkali. In a report dated November 12, 1906, to the Chief of the Bureau of Soils, Mr. Mackie reported alkali in injurious amount in only three very small areas of the vineyard. This shows that in the greater portion of the vineyard there was not sufficient alkali in the soil to hasten the death of the vines, as is often the case in the arid regions.

The experiment was also not complicated by the presence of phylloxera. The vines were carefully examined each year, but no evidence of their presence was found.

Data collected from nearly a hundred vineyards in six States in the southwestern and western United States yield similar conclusions as to the susceptibility of varieties. The most diseased varieties observed among those commonly grown in vineyards, taken in order from the highest percentage of disease to the lowest, were as follows: Muscat of Alexandria, Malaga, Mission, Flame Tokay, Black Malvoisie, and Zinfandel. Of varieties grown to a much less extent the following, arranged in the same order as before, were also found badly diseased: Black Morocco, Purple Damascus, Early Madelaine, Black Prince, Trousseau, Zabalkanski, Verdel, and Burgundy.

Among the vines commonly grown, those observed to be least affected by the disease, in the order of their immunity, were the following: Seedless Sultana, Sweetwater, Lenoir, Thompson Seedless, Feher Szagos, and Burger.

Of the vines grown to a lesser extent, the least diseased, taken in the same order as before, were Carignane, Gros Colman, Mataro, Black Prince, Black Portugal, and Grenache.

Of stocks for grafting, the Rupestris St. George, Rupestris Martin, and Herbemont appear to be almost immune.

THE RESISTANCE OF VARIETIES OF AMERICAN GRAPES.

The writer conducted no vineyard experiments with varieties of American grapes, but secured data from a number of vineyards in which the disease had appeared. Through the courtesy of Prof. W. G. Vincenheller, director of the Arkansas Agricultural Experiment Station, notes were taken on a vineyard at the station in which there was a large number of varieties of American vines and their hybrids. These vines were about 12 years old, and the disease had been observed in the vineyard for a number of years. The vines were planted on gently sloping land, consisting of an upland clay loam. The diseased vines were chiefly on the upper side of the vineyard, in such a position that the water ran from them to the vines lower down. The cultivation of the plat was made at right angles to the line of drainage, thus tending to spread the germs of disease throughout the plat by cultivation and drainage.

In the table and lists which follow the results of the experiment are given. The names of species of grapes here and elsewhere in this bulletin are in accordance with those used in Bailey's "Cyclopedia of American Horticulture." The data on the ancestry of each variety were furnished by Dr. George C. Husmann, Pomologist in charge of Viticultural Investigations of this Bureau.

TABLE III.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Fayetteville, Ark., in infected soil.*

Variety.	Variety or hybrid of—	Proportion of diseased plants resulting.
		Per cent.
Mary Ann	*Vitis labrusca*	80
Telegraph	do	40
Perkins	do	20
Dracut Amber	do	20
Duchess	*Vitis labrusca* ×	40
Black Pearl	*Vitis vulpina*	40
Faith	*Vitis vulpina* ×	20
Golden Gem	*Vitis aestivalis* ×	20
Black July	*Vitis aestivalis*	20
Lincoln	do	60
Merrimack	*Vitis labrusca* × *vinifera*	67
Opal	do	50
Goethe	do	40
Centennial	*Vitis aestivalis* × *labrusca*	40
America	*Vitis linsecomii* × *rupestris*	40
Early Market	(*Vitis vulpina* × *labrusca*) × *vulpina*	10

From the table it will be seen that varieties or hybrids of a number of species were susceptible to the disease. In the following list is given the names of those varieties or hybrids which remained free from the disease and are considered resistant, to some extent at least. Since there were, as a rule, not more than five vines of each variety, the small number must be taken into consideration as lessening the chances of infection.

The following varieties or hybrids of American grapes were free from disease:

Of the varieties derived from *Vitis labrusca:* Amanda, Arkansaw, Cambridge, Concord, Cottage, Eaton, Hartford, Illinois City, Ives, Martha, Moores Early, and Wyoming.

Of the varieties derived from *Vitis aestivalis:* Arkansas, Black Herbemont, Onderdonk, Muench, Mrs. Munson, Neva Munson, and Superb.

Of the varieties derived from *Vitis linsecomii:* Great Cluster and Lincy.

Of the hybrids of *Vitis labrusca* × *Vitis vinifera:* Barry, Black Eagle, Governor Ross, Herbert, Highland, Triumph, Campbell's Early, and Conqueror. Of *Vitis labrusca* × *aestivalis:* Gold Coin. Of (*Vitis labrusca* × *vinifera*) × (*aestivalis* × *vinifera*): Brilliant.

Of the hybrids of *Vitis linsecomii* × *aestivalis:* Admirable, Bumper, Delicious, Kemp, Hopkins, Hermann Jaeger, Marguerite, Oriole, Perry, and Vinita. Of *Vitis linsecomii* × *labrusca:* Beacon and Doctor Collier. Of *Vitis linsecomii* × (*labrusca* × *vinifera*): Bailey, Big Extra, Big Hope, Fern Munson, Long John, Newman, R. W. Munson, and W. B. Munson. Of *Vitis linsecomii* × (*aestivalis* × *labrusca*): Laussell. Of *Vitis linsecomii* × (*labrusca* × *vinifera*): Carmen. Of (*Vitis linsecomii* × *rupestris*) × (*labrusca* ×): Rupert.

Of the hybrids of *Vitis champini* × (*labrusca* ×): Chambrill. Of (*Vitis labrusca* × *vinifera*) × *aestivalis:* Lindherbe. Of *Vitis vulpina* × *labrusca:* Ironclad and Taylor. Of *Vitis vulpina* × *aestivalis:* Bell. Of *Vitis vulpina* × *munsoniana:* Elvicand. Of (*Vitis vulpini* × *labrusca*) × *vinifera:* Rommell. Of *Vitis labrusca* ×: Moores Diamond, Peter Wylie, and Early Ohio.

Through the courtesy of Dr. Husmann, the writer was permitted to take notes on a large number of vines being tested by him in several localities in California for resistance to phylloxera and alkali. Through observations made in these and other vineyards in California, where vines are being grafted and grown on resistant stocks, it has been noted that where varieties like the Muscat of Alexandria, Mission, and others susceptible to crown-gall are grafted in stocks resistant to phylloxera there is often acquired a resistance to crown-gall.

A number of vineyards were examined in central and southern California in which the vines were grafted on Rupestris St. George and Lenoir and other stocks resistant to phylloxera. These were found to be almost free from crown-gall. Neighboring vineyards of the same age where the vines were grown on their own roots were found to be very considerably or even badly diseased. This gives still greater importance to the need of obtaining resistance by grafting in resistant stocks.

THE CAUSE OF CROWN-GALL.

The earlier investigators of crown-gall mistook the conditions of environment which favor the disease for its cause. The greater number of European observers have assigned the cause of the disease to physical agents, such as late frosts and winter killing. Among those who ascribed the cause of cane galls (Grind, broussin, etc.) primarily to injury received from freezing are Dornfield (15), Köhler (33), Du Breuil (16), Beinling (2), Goethe (28), Viala (55), Frank (21), and Sorauer (48).

Garovaglio and Cattaneo (23) and Dehors (13) thought that the disease might be brought about by injuries received from insects. In addition to the action of frost and injuries by insects, some investigators, according to these writers, have advanced the opinion that a superabundance of the food supply might favor the disease.

Von Thümen (58) found a species of Fusisporium in the galls and ascribed the disease to the action of the fungus, but did not prove its pathogenesis.

Corvo (11) in 1885 noted the presence of bacteria in the tubercles, or galls, on grapevines. Cuboni (12) in 1889 observed bacterial zoogloeæ in such galls and compared them with the bacteria in olive knots. Comes (7) in 1891 thought that the disease was caused by *Bacterium gummis* and also the disease known as gummosis. Trevisan[a] named the organism as isolated by Cavara (5) *Bacillus ampelopsorae* n. sp. Cavara (5) claims to have proved the pathogenesis of this organism by inoculation with pure cultures.

Cooke (9) in 1893 described a disease on the roots of grapes much like the crown-gall. He asserted that he found a species of Plasmodiophora in the galls. This in 1903 he designated as *Plasmodiophora vitis* (10). He did not, however, prove the pathogenesis of the organism he found.

Woodworth (60) mentions the finding of a species of *Micrococcus* in grape galls which he grew in a pure culture, but he did not prove the pathogenesis of the organism.

Reddick (41) in 1909 described a fungus *Fusicoccum viticolum*, which he isolated a number of times from the cane galls of grapevines in New York. He ascribed the disease to this fungus.

The writer, in July, 1903, in a study of the disease at Bernalillo, N. Mex., found constantly occurring in the tissues of grape, cane, and root galls and in adjacent diseased tissues a motile bacterial species which was isolated repeatedly and grown in pure cultures in poured agar plates and slant agar tubes in a culture medium consisting of a decoction of celery added to McDougal's culture solution. In agar plates the colonies were round, with a smooth edge, whitish in color, and viscid when drawn out with a needle. No inoculations were made with the organism at the time. These cultures were lost in transit to St. Louis, Mo., where they were sent for further study.

Again, in July, 1904, a number of organisms, including five kinds of bacteria, were isolated from grape root galls. These were grown in pure cultures and inoculated in young Muscat of Alexandria and in Tokay grape seedlings. One of these organisms was in appearance similar to the one found in 1903, and of three Muscat of Alexandria seedlings inoculated with a pure culture of it two became diseased with galls at the point of inoculation. Wounded control plants remained healthy. Although the limited nature of the experiment rendered the results inconclusive, owing to the urgency of the immediately practical aspect of these investigations, this work was not prosecuted further at that time.

In April, 1907, Smith and Townsend (45) of the Bureau of Plant Industry, published an article describing a plant tumor of bacterial origin. They gave conclusive proof of the pathogenesis of the organism *Bacterium tumefaciens*, n. sp., which was isolated from the galls of the Paris daisy, grown in pure cultures, and studied. This organism, when inoculated into healthy plants of tobacco, tomato, potato, sugar beet, hop, and peach produced galls at the point of inoculation.

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[a] Saccardo. Sylloge Fungorum, vol. 8, p. 983.

Wounded control plants of the same species remained free from the disease. This investigation established the relationship of a number of gall diseases and the cause of the crown-gall of the peach, etc. No inoculations were reported at this time on grapevines, but Doctor Smith informs the writer that one successful inoculation was made on the grape, April 3, 1907, and that 18 successful inoculations were obtained in May of that year (all that were inoculated).

During the first week in April, 1907, an organism similar to the one found in 1903 was isolated by the writer from grape root galls and inoculations were made into healthy peach, apple, and apricot seedlings during the second week in April. Of 14 peach seedlings inoculated 9 became diseased with galls at the point of inoculation; of 12 apricot seedlings 6 became similarly diseased; of 5 apple seedlings inoculated none became diseased. The final count was made on November 5, 1907. Wounded control plants of the same kind remained free from disease.

In December, 1908, at a meeting of the Botanical Society of America, Doctor Townsend (51a) reported the results of further experiments with the organism from the Paris daisy. This organism when inoculated into other plants produced galls on the tomato, potato, tobacco, sugar beet, hop, carnation, grape, raspberry, peach, and apple. This proves that galls on the grape may be produced by *Bacterium tumefaciens* and are identical in origin with those on a number of other plants. The galls obtained on the grape by Townsend were both on the canes and roots, and resembled in form the galls on the roots of the grape.

THE COMMUNICABILITY OF CROWN-GALL.

OBSERVATIONS BY OTHER INVESTIGATORS.

Very little has been published on the communicability of crown-gall, except in the line of opinions by observers. These will not be cited.

Lataste (34) communicated the disease to the root of a growing grapevine by binding a piece of living grape gall over a wound.

RESULTS OF EXPERIMENTS.

Experiments with seedlings.—In 1908 the writer (30) published the results of part of a series of experiments on the communicability of the crown-gall from a number of host plants, showing that the disease is communicable from pieces of living tissues of soft crown-galls placed in wounds on the roots of the host plants. These experiments proved the identity of the soft galls of the apple and pear with those of the stone fruits, raspberry, blackberry, and rose. A portion of these experiments was devoted to the communicability of the grape crown-gall. The results of these and other experiments will now be given.

Beginning with 1903 plants were grown each year from seed in the manner described on page 14. Some of these were inoculated at the age of from 3 to 6 months by inserting pieces of living grape root galls into wounds at or below the surface of the soil. Others were wounded without inoculations and set aside as a control. The results of these inoculations were negative in many instances. A summary of the results of these experiments for five years is given in Table IV. Both European and American varieties of grapes were used.

TABLE IV.—*Summary of the results of inoculating seedlings of various kinds of plants with grape crown-gall, 1903–1907.*

Kind of seedlings.	Inoculated plants.			Wounded plants.		
	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Almond	34	91.2	8.8	62	100.0	0.0
Apple	21	100.0	.0	28	100.0	.0
Apricot	46	100.0	.0	80	100.0	.0
Blackberry	21	95.2	4.8	10	100.0	.0
Chestnut	10	100.0	.0	10	100.0	.0
Cherry	10	80.0	20.0	7	100.0	.0
Grape	262	85.5	14.5	358	99.7	.0
Peach	73	69.9	30.1	71	100.0	.0
Pear	5	100.0	.0	5	100.0	.3
Plum	14	100.0	.0	6	100.0	.0
Raspberry	50	96.0	4.0	125	100.0	.0

The results of the experiments prove the communicability of the grape crown-gall (14.5 per cent) with pieces of galls. They also show that the disease is communicable as follows: To the almond, 8.8 per cent; blackberry, 4.8 per cent; cherry, 20 per cent; peach, 30.1 per cent; and raspberry, 4 per cent. The inoculations on the apple, apricot, chestnut, pear, and plum gave negative results.

Another set of experiments was conducted similarly with grape seedlings, except that the inoculations were made with galls from other host plants. Table V shows the results:

TABLE V.—*Summary of the results of inoculating grape seedlings with galls from other host plants.*

Galls taken from—	Number of grapevines inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	8	100.0	0.0
Apple	81	100.0	.0
Blackberry	38	100.0	.0
Peach	44	93.2	6.8
Pear	13	100.0	.0
Plum	18	100.0	.0
Raspberry	52	92.3	7.7
Rose	57	97.3	2.7
Control	359	99.7	.3

The results from this experiment do not differ radically from the former as regards hosts. They indicate the communicability to the grape from the following hosts: Peach, 6.8 per cent; raspberry, 7.7 per cent; rose, 2.7 per cent. No communicability was shown in the cases of the galls from the almond, apple, blackberry, pear, and plum.

A third set of experiments was conducted in the greenhouse with apparently healthy pear seedlings selected from nursery stock, which were washed clean and inoculated with pieces of crown galls from the roots of grape and other host plants. The results are given in Table VI:

TABLE VI.—*Summary of the results of inoculating healthy pear seedlings with grape and other galls.*

Galls taken from—	Number of pear trees inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	93	96.8	3.2
Apple	379	99.2	.8
Blackberry	200	91.0	9.0
Cherry	100	83.0	17.0
Grape	387	99.2	.8
Peach	293	78.2	21.8
Pear	83	100.0	.0
Raspberry	197	93.4	6.6
Rose	173	90.2	9.8
Control	196	99.5	.5

The results of the experiment show that the disease is communicable to pear seedlings from other host plants as follows: Almond, 3.2 per cent; apple, 0.8 per cent; blackberry, 9 per cent; cherry, 17 per cent; grape, 0.8 per cent; peach, 21.8 per cent; raspberry, 6.6 per cent; rose, 9.8 per cent. Negative results were obtained again with the pear, also with the apple and grape, on account of the fact that the control plants were diseased in almost the same amount.

The results of these experiments indicate that the crown-gall is communicable to some extent from the grape to the stone fruits and blackberry and raspberry, and vice versa. The degree of communicability to the apple from the grape appears to be almost a negligible quantity.

Experiments with older vines.—The earlier investigators who assumed that freezing, injuries, etc., were the cause of crown-gall erred, but in doing so found the conditions that favor the communicability of the organism causing it.

The cause of the disease can not be ascribed to injuries due to freezing, since the disease is found on plants grown and inoculated in the greenhouse at temperatures far above freezing. Wounds are apparently necessary for the entrance of the organism causing the disease, and freezing produces wounds. Cane galls were observed forming in injuries to vines caused by late frosts at Bernalillo, N. Mex. They were also noted forming in wounds received by cultivation and in those due to pruning. The pruning knife apparently may disseminate the organism.

In a vineyard under the observation of the writer at Bernalillo, a virgin piece of soil was leveled and planted with Mission vines of the New Mexico variety. These were placed on a terrace slightly lower than an older vineyard containing the badly diseased vines of an earlier planting. The new vineyard was planted with healthy vines grown from cuttings taken from healthy vines. The vines grew well and all remained healthy for a year. Then a careless workman who was irrigating by surface irrigation allowed the water to break through a ridge and flow directly from the old vineyard across the center of the new one. The following year the vines in the overflowed portion of the new vineyard became diseased. The fourth year the disease had spread by irrigation to all portions of the vineyard.

In central California it was noted that vineyards that were subirrigated showed little crown-gall, but those of the same varieties in adjacent vineyards that were surface-irrigated showed much of the disease in all portions of the vineyards.

Bees probably communicate the disease as carriers of bacteria found in the galls and the adjacent diseased tissues. In the spring they were observed feeding on the exuding sap after the vines were pruned and then passing from diseased vines to healthy ones.

That the disease can be communicated by means of diseased cuttings has already been shown by the results of the experiment previously described in this bulletin.

THE CURE OF CROWN-GALL.

NEGATIVE RESULTS FROM EXPERIMENTS WITH FUNGICIDES.

As stated on a previous page, the experimental plat at Bernalillo, N. Mex., originally was planted with about 5 acres of grapevines of the Mission (California) variety, and these became badly diseased. All the diseased vines were treated as follows in the spring of 1903 to control the disease: The ground was removed from the base of the vines and all the galls cut away; then the wound was covered with a paste made of copper sulphate and lime.

Some of the vines were probably killed by this treatment, but the disease was not checked, as galls broke forth anew from the vines on other portions of the plants.

The following autumn a portion of the vineyard was again treated as follows: The vineyard was divided into blocks of five rows of 60 vines each. On three adjacent rows of vines about equally diseased the soil was removed around the base of the plants, the galls removed by excision with a sharp knife, and the wound washed with a fungicide. The galls were cut from the vines in an adjacent row, but no chemicals were applied. This row served as a wound control. On a fifth row of vines the galls were undisturbed, as a further control to treatment by excision and by the use of fungicides. This block of five rows made an experiment.

Several such blocks were similarly prepared and three rows treated in each, using the following water solutions of chemicals, a different one in each block: (1) A 2 per cent solution of copper sulphate; (2) a 5 per cent solution of iron sulphate; (3) a 2 per cent solution of formalin. In a fourth block the wound was covered with powdered sulphur. Four more blocks were given the foregoing treatments except that each plant received in addition an application of a fertilizer containing bone phosphates and nitrate of soda.

During the winter which followed many vines in all of the rows died, and of those that lived none certainly recovered. The rows treated showed no improvement over the others. The experiment resulted so badly that the vines were removed and replaced with other varieties in an attempt to secure resistant varieties. Although these experiments failed to accomplish the cure of the diseased vines they can be considered only as indicative of the probable futility of curing the disease by excision of the galls followed by the application of a fungicide. They do not prove the impossibility of a cure by some other method of surgical or chemical treatment.

THE PREVENTION OF CROWN-GALL.

The results of the studies and experiments with the disease indicate the necessity for prevention rather than cure. This can be accomplished either by the use of resistant vines or by grafting nonresistant vines on resistant stocks.

RESISTANT VINES SHOULD BE PLANTED ON THEIR OWN ROOTS.

In the experiment previously described, where 24 of the best varieties were grown in infected soil to test their resistance to attacks by the disease, it was found that a number of varieties were quite resistant to crown-gall, as follows: Rupestris St. George, Feher Szagos, Sweetwater, Golden Chasselas, Seedless Sultana, Carignane, Grenache, Gros Colman, and Mataro. These varieties will succeed well on their own roots. More than a hundred varieties are being tested by Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, in an experiment begun in 1904 in cooperation with this Bureau but now being completed by the station. An additional number of resistant varieties will be determined from this experiment.

RESISTANT STOCKS SHOULD BE USED FOR GRAFTING NONRESISTANT VARIETIES.

The Rupestris St. George variety gave the highest degree of resistance to the disease and grew vigorously. This variety is of no value except as a stock for the purpose of bench grafting. Its resistance to the disease being very high makes it a valuable vine for this purpose. Its resistance to the phylloxera makes it doubly valuable, since sooner or later this pest will be likely to appear in every vineyard region where European varieties of grapes are grown.

The Lenoir variety, used as a stock for grafting, is also valuable as a wine grape. Although quite a number of vines of this variety became slightly diseased in the experiments, none were seriously affected, and it is recommended as a good vine for the Southwest wherever the crown-gall has appeared, either when grown for its fruit or as a stock for ingrafting more susceptible varieties. It is not within the province of this bulletin to enter fully into the discussion of all the varieties of vines resistant to the phylloxera, most of which will very probably be found resistant to the crown-gall.

In localities where the ravages of the disease are marked, it is not advisable to plant the Mission variety, especially the Mission from California, the Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, or Riesling varieties unless grafted upon resistant stocks.

OTHER MEANS OF PREVENTION.

When vines are grown from cuttings, care should be taken to secure cuttings from vineyards free from the disease. Such cuttings should be grown in soil where vines have not been grown for five or more years.

In planting vines or cuttings in the arid regions it is best to plant them deeply, so that not more than one bud or eye will remain above the soil. This will protect them both from freezing and from the burning sun, both of which are injurious to the young vines and lower their vitality even though an entrance of the disease may not take place.

In case a vineyard or locality is free from crown-gall it is best to be exceedingly careful where vines are purchased for planting. That the nursery is free from the disease should be ascertained before purchasing varieties of European grapes. It is better, where possible, to propagate vines by bench-grafting on healthy stocks grown at home from cuttings selected from healthy vines.

SUMMARY AND RECOMMENDATIONS.

The disease of grapes in this country designated as black-knot, crown-knot, root-knot, crown-gall, and as root tumors has been known for many years. In Europe it has been known for a longer period as "Grind," "Kropf," "broussins," "rogna," "tuberculosi," etc.

Two forms of the disease occur commonly on varieties of *Vitis vinifera* in the southwestern and western United States. One form occurring as rough, often hard, excrescences on the canes of grapevines is designated as cane galls in this bulletin and is also known as "black-knot," "Grind," "broussins," "rogna," etc. (Pl. II, fig. 2.) The other form, occurring at or below the surface of the ground on the crowns and roots of the vines in the form of soft galls, is designated as root galls in this paper, but is also known as "tumors," "Kropf," "rogna," and "tuberculosi." (Pl. III, fig. 1.)

The crown-gall, or a similar disease, is widely disseminated in many parts of the world, especially where varieties of *Vitis vinifera* are grown.

The entrance of the disease in vines is favored by injuries, such as those due to freezing and late frosts, to pruning, etc. The effect of the disease is very destructive, often killing or stunting nearly all the vines in a vineyard in a few years, resulting in a heavy loss in many localities, especially in the western United States.

The galls usually develop annually, rotting away at the end of the growing season, the rot killing the adjacent tissues and cutting off the circulation of the vine, having much the effect of a cancer.

A great variation in the resistance to the disease is shown by many varieties of European and American grapes. Of European grapes the Muscat of Alexandria and the Mission of California were found to be the most susceptible varieties. No species of *Vitis vinifera* was found to be entirely immune. Some hybrids with American varieties possess a high degree of resistance. Among these are the Rupestris St. George and other similar varieties. The Lenoir possesses a high degree of resistance and is in many ways desirable as a grafting stock.

In New Mexico the varieties found most resistant were Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lencir. These vines are more or less resistant on their own roots and are recommended for planting in infected vineyards. A higher resistance to the disease can be obtained by grafting these or other desirable varieties on such stocks as the Rupestris St. George and the Lenoir, which are also resistant to phylloxera.

The disease is communicated in a number of ways: (1) By the water of irrigation; (2) by cuttings from diseased plants; (3) probably by the pruning knife; and (4) by insects.

As a protection against frost injuries, cuttings or young vines should be planted deeply in the soil, especially in arid regions, allowing only one bud to project above the surface of the ground.

Cuttings and young vines should be secured from healthy surroundings. It is better to use vines grown under one's personal supervision than to purchase from a vineyard or nursery known to be infected with the disease.

Grapevines should be pruned in the spring either before or just after the period of sap flow, the time varying with the locality. They should be protected in winter from freezing where necessary, and the protective covering should not be removed until the danger of injury is passed, because the wounds produced by late frosts afford a means of entrance to the organisms causing the disease.

Finally, in a new vineyard resistant vines should be planted if possible. If it is necessary to grow nonresistant vines they should be grafted on stocks that are resistant. All diseased vines should be burned as soon as they are discovered and replaced with healthy resistant vines.

INDEX TO LITERATURE.

A bibliography of the crown-gall of the grape follows:

1. Beach, S. A., Lowe, V. H., and Stewart, F. C. Grape diseases—black-knots. Report of the Botanist for Geneva (New York) Agricultural Experiment Station. Report 19, 1901, p. 189.
2. Beinling, E. Ueber das Auftreten von Rebenkrankheiten im Grossherzogtume Baden im Jahre 1891. Zeitschrift für Pflanzenkrankheiten, vol. 2, 1892, pp. 207–210.
3. Blunno, M. A. Cancerous disease of the grapevine. Agricultural Gazette of New South Wales, vol. 12, 1901, pp. 1079–1081 and 3 pl.
4. Cavara, F. Aperçu sommaire de quelques maladies de la vigne parues en Italie en 1894. Revue Internationale de Viticulture et de Oenologie, vol. 6, 1895, pp. 447–449.
5. ——— Tuberculosi della vite. Intorno alla eziologia di alcune malattie di piante coltivate. Le Stazioni Sperimentale Agrarie Italiane, vol. 30, 1897, pp. 483–487.
6. Cazalis, F. Le Messager Agricole du Midi, 2d ser., 1873, pp. 142–144.
7. Comes, O. Bacillus ampelopsoræ Trev. Batterio della rogna della vite. Crittogamia Agraria, vol. 1, 1891, pp. 522–525.
8. ——— La malattia della rogna. Della principali malattie delle piante coltivate nella Sicilia. Atti della Giunta per l' Inchiesta Agraria, vol. 13, pt. 1, fasc. 3, 1885, pp. 14–18.
9. Cooke, M. C. Vine root clubbing. Gardeners' Chronicle, 3d ser., vol. 13, 1893, p. 711.
10. ——— Vine root clubbing. Plasmodiophora vitis. Journal Royal Horticultural Society, vol. 28, 1903, pp. 321–322, pl. 14 and fig. 12.
11. Corvo, Andrade. Sur le rôle des bacilles, dans les ravages attribués au Phylloxera vastatrix. Comptes Rendus de l'Académie des Sciences, Paris, vol. 101, 1885, pp. 528–530.
12. Cuboni, G. Patalogia vegetale.—Sui bacteri della rogna della vite. Atti della Reale Accademia dei Lincei, ser. 4, vol. 5, 1889, pp. 571–573.
13. Dehors. Sobre una nueva producción morbosa en las raices de las parras chilenas. Actes de la Société Scientifique du Chili, vol. 4, 1894, pp. 222–223.
14. De Lapparent, H. [Note on *broussins*.] Bulletin de la Société des Agriculteurs de France, vol. 42, 1897, pp. 21–23.
15. Dornfield, J. Der Grind. Weinbauschule, 1859, p. 121.
16. Du Breuil, E. Intempéries. Gelées du printemps. Les vignobles et les arbres à fruits a cidre. 1875, pp. 228–229 and fig. 167.
17. Duffourc-Bazin, G. Le broussin. Revue de Viticulture, vol. 13, 1900, pp. 623–625.
18. Durand, E. Broussins. Les maladies de la vigne. Flora et faune des parasites de la vigne, 1907, pp. 54–55 and fig. 21.
19. Fabre, E., and Dunal, F. Observations sur les maladies régnantes de la vigne. Bulletin de la Société Centrale d'Agriculture du Département de l'Hérault, vol. 40, 1853, p. 46 and pl. 4.
20. Fletcher, James. "Black-knot" of the grape. Report for 1889. Canadian Agricultural Experimental Farms, 1890, p. 87.

21. Frank, A. B. Der Krebs, oder Grind des Weinstockes. Die Krankheiten der Pflanzen, vol. 1, 1895, pp. 209–210.

22. Galloway, B. T. Black knot of the grape. Bulletin 8, Botanical Division, U. S. Department of Agriculture, 1889, p. 63.

23. Garovaglio, S., and Cattaneo. Studi sulle dominanti malattie dei vitigni. Della rogna dei vitigni. Archivio del Laboratorio Crittogamica de Pavia, vol. 2–3, 1879, pp. 248–252, pl. 6, figs. 3 and 4.

24. Garcia, Fabian. European grapes. Observations on the crown-gall. Bulletin 58, New Mexico Agricultural Experiment Station, 1906, pp. 19, 28–29.

25. Giard, Alfred. Sur la nature du broussin. Revue de Viticulture, vol. 8, 1897, pp. 80–81.

26. Goethe, R. Ueber den Grind und den Schwarzbrenner der Reben. Der Weinbau, 1878, p. 295.

27. ——— Mittheilungen über den schwarzen Brenner und den Grind der Reben. Berlin and Leipzig, 1878.

28. ——— Die Ursache des schwarzen Brenners an den Grind der Reben. Biedermann's Centralblatt für Agric.-Chemie, vol. 9, 1876, pp. 142–144. Deutsche Landwirtschaftliche Presse, vol. 2, 1875, p. 618.

29. ——— Les exostoses de la vigne. La Vigne Américaine, vol. 6, 1882, pp. 136–144.

30. Hedgcock, George G. The cross-inoculation of fruit trees and shrubs with crown-gall. Bulletin 131, pt. 3, Bureau of Plant Industry, U. S. Department of Agriculture, March, 1908, pp. 21–23.

31. ——— The crown-gall disease of the grapevine. Bulletin 58, New Mexico Agricultural Experiment Station, 1906, pp. 30–31.

32. Joly, N. Le Messager Agricole du Midi, 2d ser., 1873, pp. 142–144.

33. Köhler, J. M. Pflanzen Krankheiten. Raude (Kropf, Grind, Schorf). Der Weinstock und der Wein, 1869, pp. 205–206.

34. Lataste, F. Contagiosité et prophylaxie de la maladie tuberculeuse de la vigne. Actes de la Société Scientifique du Chili, vol. 6, 1896, pp. 74–77; also Comptes Rendus, vol. 123, July 6, 1896, pp. 200–202.

35. Lawrence, W. H. Some important plant diseases of Washington. Bulletin 83, Washington Agricultural Experiment Station, 1907, p. 13 and fig. 3.

36. Lelong, B. M. Root-knot. Report of the California State Board of Horticulture, vol. 4, 1894, p. 313.

37. Martelli, U. Ceppi di vite affeti della cosi della tuberculosi. Nuovo Giornale Botanico, Florence, vol. 23, April, 1891, p. 350.

38. Planchon, J. E. Les exostoses fungoïdes de la vigne connues sous le nom de broussins. La Vigne Américaine, vol. 6, 1882, pp. 110–117.

39. Prillieux, E. E. Tumeurs ligneuses ou broussins des vignes. Bulletin de la Société Botanique de France, vol. 35, 1888, pp. 393–395.

40. Ravaz, L. Le broussin de la vigne. Revue de Viticulture, vol. 7, 1897, pp. 743–745.

41. Reddick, Donald. Necrosis of the grapevine. Bulletin 263, Cornell (New York) Agricultural Experiment Station, 1909, pp. 323–343 and figs. 41–57.

42. Seillan, J. Le broussin ou exostose. La Vigne Américaine, vol. 6, 1882, pp. 117–120.

43. Selby, A. D., and Van Hook, J. M. Dying of bearing grapevines. Localized stem blight in Ohio vineyards. Circular 64, Ohio Agricultural Experiment Station, 1907, pp. 1–6.

44. Smith, Erwin F. Stem and root tumors. Journal of Mycology, vol. 7, 1894, pp. 376–377 and pl. 38.

44a. ——— The etiology of plant tumors. Science, n. s. vol. 30, no. 763, August 13, 1909, p. 223.

45. Smith, Erwin F., and Townsend, C. O. A plant tumor of bacterial origin. Science, n. s., vol. 25, 1907, pp. 671–673.

45a. ——— ———. Ein Pflanzentumor bakteriellen Ursprungs. Centralblatt für Bakteriologie, pt. 2, vol. 20, 1907, pp. 89–91.

46. Sorauer, P. Der Krebs (Grind) des Weinstockes. Handbuch der Pflanzenkrankheiten, 1908, vol. 1, pp. 594–596.

47. ——— Die Bakteriosen der Vitaceen. Handbuch der Pflanzenkrankheiten, 1908, vol. 2, p. 57.

48. ——— Der Krebs (Grind) des Weinstockes. Handbuch der Pflanzenkrankheiten, vol. 1, 1886, pp. 414–416 and 418 and fig. 21.

49. Stewart, F. C., and Blodgett, F. G. Grape diseases. Black-knot. A fruit-disease survey of the Hudson Valley in 1899. Bulletin 167, Geneva (New York) Agricultural Experiment Station, 1899, pp. 298–299 and pl. 4,

50. Stewart, F. C., Rolfs, F. M., and Hall, F. H. A fruit disease survey of western New York in 1900. Bulletin 191, Geneva (New York) Agricultural Experiment Station, 1900, p. 312.

51. Toumey, J. W. An inquiry into the cause and nature of crown-gall. Bulletin 33, Arizona Agricultural Experiment Station, 1900, pp. 29–30.

51a. Townsend, C. O. A bacterial gall of the daisy and its relation to gall formations on other plants. Science, n. s., vol. 29, no. 737, February, 1909, p. 273.

52. Trécul, A. Mémoire sur le développement des loupes et des broussins. Annales des Sciences Naturelles Botaniques, ser 3, vol. 20, 1853, pp. 65–80 and pl. 7.

53. Twight, E. H. Introduction—Black-knot. Observations on some vine diseases in Sonoma County, California. Bulletin 168, California Agricultural Experiment Station, 1905, p. 5.

54. Van Hall, C. J. J. Ziekte van den Wijnstok, "rogna della vite" (Bacillus ampelopsorae Trev.) Bijdragen tot de Kennis der Bakterieele Plantenziekten, 1902, p. 84.

55. Viala, P. Broussins. Les maladies de la vigne, 1887, pp. 441–443 and figs. 192–193.

56. ——— Broussins sur les racines. Revue de Viticulture, vol. 5, 1896, p. 152.

57. ——— Gelées de printemps.—Broussins. Les maladies de la vigne, 3d edition, 1893, pp. 478–490 and figs. 227–232.

58. Von Thümen. Der Pilz-Grind der Weinreben. Aus dem Laboratorium der Versuchstation für Wein und Obstbau, Klosterneuberg, bei Wien, 1884, no. 5.

59. Whipple, O. B. Crown-gall. Western slope fruit investigation. Report of field horticulturist. Bulletin 118, Colorado Agricultural Experiment Station, 1906, p. 11.

60. Woodworth, C. W. Crown-knot. Report for 1894-1895, California Agricultural Experiment Station, 1896, pp. 231–232.

61. Woodworth, C. W., and Wickson, E. J. Root knots on fruit trees and vines. Bulletin 99, California Agricultural Experiment Station, 1892, pp. 1–4.

62. ——— Root knots on trees and vines. Report for 1892-1894, California Agricultural Experiment Station, 1894, pp. 436–440.

63. Zacharewicz, E. Les broussins dans les vignes de Vaucluse. Revue Internationale de Viticulture, vol. 1, 1894, pp. 119–120.

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DESCRIPTION OF PLATES.

Plate I. *Frontispiece.* A 4-year-old Mission grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased both above and below the surface of the ground. The young offshoot is the result of an attempt on the part of the vine to renew itself.

Plate II. Fig. 1.—A 4-year-old Muscat of Alexandria grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased with confluent root galls. Fig. 2.—Another Muscat of Alexandria grapevine from the same lot as that shown in Figure 1 diseased with confluent root galls below and cane galls above.

Plate III. Fig. 1.—Root galls on a badly diseased Flame Tokay grapevine from the same vineyard as those shown in Plate II. (One-third natural size.) Fig. 2.—A Muscat grapevine diseased with a globose gall, resulting from an inoculation.

Plate IV. Fig. 1.—View of a portion of the experimental vineyard at Bernalillo, N. Mex., before the diseased Mission vines were replaced with other varieties. Fig. 2.—A view of a portion of the experimental vineyard at Bernalillo, N. Mex., after it had been planted with resistant vines.

PLATE II.

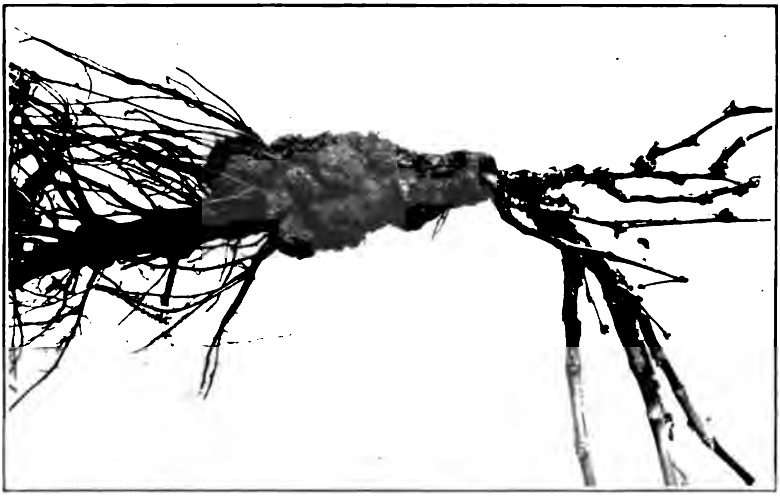

Fig. 1.—A Muscat of Alexandria Grapevine Diseased with Confluent Root Galls.

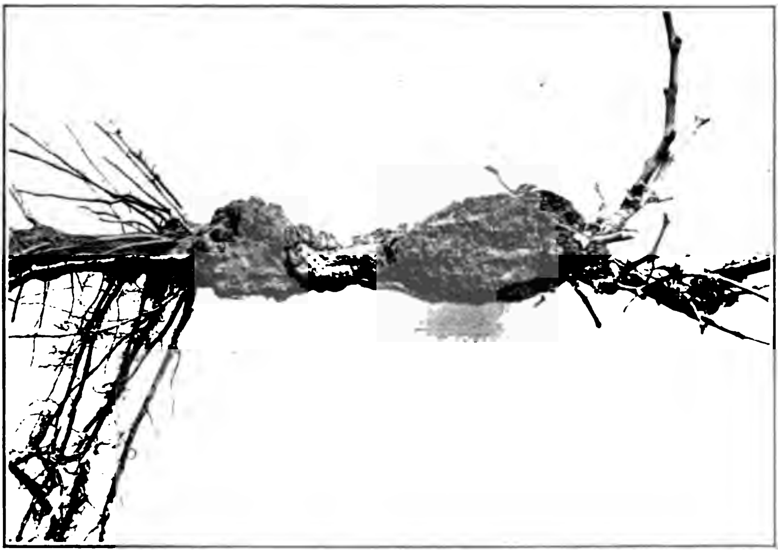

Fig. 2.—A Muscat of Alexandria Grapevine Diseased with Confluent Galls on Both the Cane and Root.

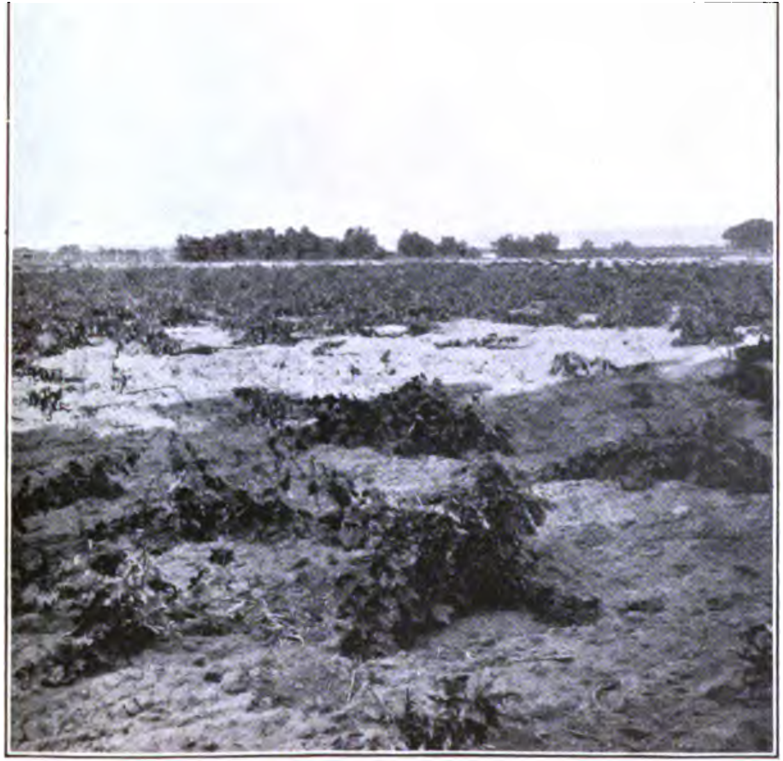

FIG. 1.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., SHOWING DISEASED MISSION GRAPEVINES.

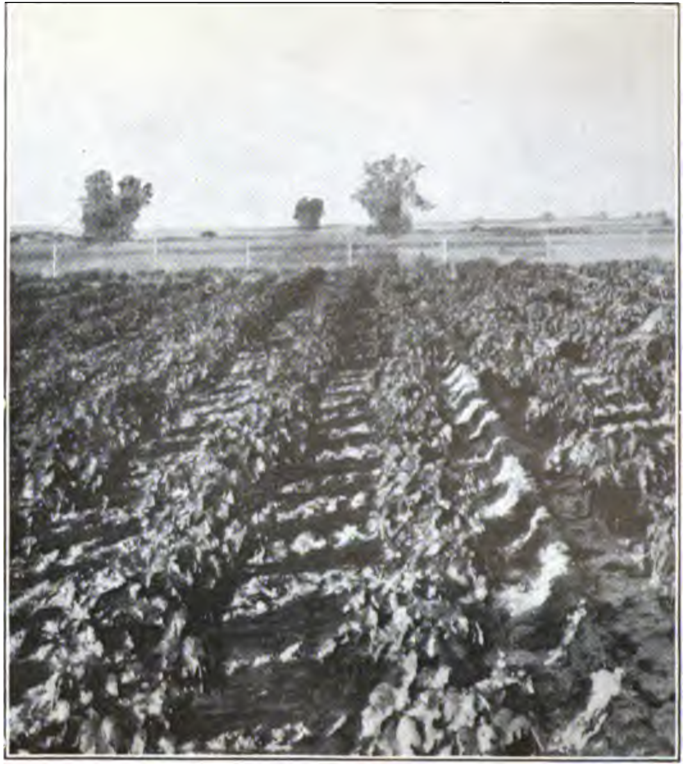

FIG. 2.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., AFTER IT HAD BEEN PLANTED WITH RESISTANT GRAPEVINES.

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BUREAU OF PLANT INDUSTRY,

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 184.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRODUCTION OF VEGETABLE SEEDS:

SWEET CORN AND GARDEN PEAS AND BEANS.

BY

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SUPERINTENDENT OF VEGETABLE-TESTING GARDENS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 15, 1910.

Sir: I have the honor to transmit herewith a manuscript entitled "The Production of Vegetable Seeds: Sweet Corn and Garden Peas and Beans," by Dr. W. W. Tracy, Superintendent of Vegetable-Testing Gardens, Horticultural Investigations, and recommend that it be published as Bulletin No. 184 of the special series of this Bureau.

Doctor Tracy is recognized by the American seed trade as an authority on all matters relating to the nomenclature, growing, harvesting, and handling of vegetable seeds. This paper is based on the author's personal experience in this field of activity.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

writer believes that they may be greatly improved, and to the advantage of both seedsman and farmer.

There are several possible improvements in the practice of vegetable-seed growing.

(1) Seed growers, dealers, and planters need to change their belief and practices regarding the relative importance of "sample" and "stock."[a] In many cases purchasers will choose the better looking of two samples of seed at a higher price, although they know nothing of the stock from which it was grown except that it is said to be of the variety named, rather than the poorer looking sample, which though quite possibly of lower viability, is known to have been grown from well-bred stock seed. Seedsmen should emphasize far more than they do, through their salesmen, catalogues, and price lists, the superior value of seed produced from stocks which are known to have been carefully bred to a certain distinct varietal character. They should refuse to handle seeds which they do not know were grown from pure and true stocks. Planters should not be tempted by low prices to purchase seed of unknown or uncertain quality, but should always buy that which they believe to be the purest and truest stock, paying comparatively little attention to appearance, or even to viability.

(2) The seedsman should change his attitude toward the contracting farmer, looking upon him as a seed grower rather than as a mere cultivator and making every effort to increase his interest in and knowledge of the varietal character of the sort of seed he grows, as well as the special cultural methods which will best develop its distinguishing merits. This would necessitate the seedsman's making a greater effort to place his growing contracts not only with cultivators who are favorably situated as to climate and soil for growing certain seeds but with those who are likely to continue to grow seeds and by a better knowledge of their cultural requirements secure greater uniformity and stability. In order to induce such men to plant seed crops it might be necessary to pay better prices for growing, but this would be more than balanced, even financially, by the elimination of careless and incompetent growers who are apt to fail to deliver the expected crop and through whose negligence carefully selected stocks are often lost. The advantage accruing from a clientage of experienced and careful growers interested in the varietal characteristics of the stocks they grow and who by greater care and better cultural methods would grow not only better seed but in more

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[a] Seedsmen commonly use the word "sample" as referring to the viability, color, and appearance of a lot of seed, and the term "stock" as referring to the quality, purity, and evenness of type resulting from the line of breeding and ancestry.

uniform quantities, thus lessening the liability to alternating periods of scarcity and surplus, would more than offset the higher price paid the farmer.

(3) There is a possibility of great improvement on the part of the farmer grower through more careful study not only of the particular crop but of the variety best adapted to his own conditions of soil and climate and of the cultural method which will give him the greatest certainty of a crop that shall be bright, clean, highly viable, and best suited for seedsmen's use. Many cases are known where two crops from the same stock seed were grown on adjacent farms by men who were considered equally good cultivators and one crop was clean, viable, and thoroughly satisfactory for use as seed while the other, solely because of difference in handling, was so discolored and lacking in viability that it was worthless for seedsmen's use.

Farmers seldom appreciate the importance to the seedsman of receiving the full quantity of seed contracted for. This in some cases is so great as to justify seedsmen when dealing with a professional seed grower in making an advance of from 10 to 50 per cent in price for a guaranteed delivery of the full amount of the contract. We may question the wisdom of making a guarantee of this kind, but the fact that such prices are paid shows how important and valuable the seedsman regards the careful handling of the crop so as to secure the expected return of usable seed.

(4) There is a possibility of great improvement through the use of better stock seed. A considerable proportion of the seed now grown, even for the most careful of our seedsmen, is in reality the product of the general crop rather than of selected stock seed. Most farmers, and even many seedsmen, fail to adequately appreciate the practical importance of absolute uniformity of stock and that such uniformity can only be secured by the use of stock seed which was not only the product of plants of the exact varietal character desired but which had behind it the greatest possible number of generations of just such plants.

The seedsman and farmer should come to a very clear understanding as to the exact form wanted in each variety. This should be established by samples, photographs, and full varietal descriptions, and it should be rigidly adhered to in selecting stock seed. An interested and intelligent farmer grower who confines his seed crop to a single variety of a species is in a better position to select stock seed, and is able to do it better and cheaper than a seedsman, and he should be fully advised as to the exact varietal character wanted and instructed to grow a sufficiency of the best possible stock for his own crops, if nothing more.

The cultural methods which will give the best returns with grain crops are generally equally well adapted to the growing of a crop for seed, but with the latter it is important that special care be taken that the seed be pure and that the percentage of viability is high. The best methods for securing crops of such seed will vary with different species and may be considered separately.

THE GROWING OF SWEET CORN FOR SEED.

The use of sweet corn, at least of the quality and in the quantities now common, is comparatively modern. Seedsmen handled very little sweet corn previous to 1825 or 1830, and for the next twenty or twenty-five years practically all of the seed used came from New England. In later years the growing of sweet-corn seed gradually extended into western New York, northern Ohio, Michigan, Iowa, and Nebraska, until at present fully 80 per cent of the sweet-corn seed produced in the United States is grown at points west and north of Cleveland, Ohio. South of the latitude of that city sweet corn is so liable to injury from the bollworm that it can seldom be profitably grown for seed.

INFLUENCE OF LOCATION ON SWEET CORN FOR SEED.

The corn plant is influenced as to size of stalk and earliness of maturity by climatic conditions, and this effect is transmitted through the seed, so it is desirable that seed of sorts in which earliness is an important element of value should be grown as far north as it can be fully ripened and cured.

The qualities of sweetness and tenderness in green corn are also influenced by soil and climatic conditions, but there is a difference of opinion as to how far this influence is carried in the seed. The corn packers of Maine insist that green corn grown in the North from northern-grown seed is superior to that which can be produced from seed grown farther south. The Maryland packers insist that they can get not only more but sweeter and more tender corn from seed grown in their own locality. In both cases the superior results obtained from local-grown seed may be accounted for by the fact that seed grown in any locality for a number of generations has been found by experimentation to give better results in that locality than seed of the same stock equally well grown elsewhere.

The belief that the use of northern and eastern grown seed will result in better and sweeter green corn is so general that seedsmen's catalogues are often so worded as to give the impression that all the sweet corn they offer is grown in the East, but very often seed bought of an eastern seedsman and supposed to be eastern grown was actually produced in the West. There are many facts that seem to indicate that the gardener's prejudice against western seed is well founded.

If a field of sweet corn is planted with two lots of seed of the same variety, one eastern and the other western grown, and ears as uniform as possible as to maturity and quality are gathered from the two parts of the field, processed, and canned in the same way, experts can with a fair degree of certainty decide which lot of seed the corn in different cans was grown from, and they will generally declare that the corn from the eastern-grown seed is the better.

This difference in quality is much more noticeable in the earlier than in the later maturing sorts and with some lots of seed than with others. The belief that it actually exists is so general that it affects the relative market value both of canned corn and of sweet-corn seed. If we carefully select ears grown from eastern and from western seed which are in exactly the same stage of maturity, chemical analysis fails to detect any constant difference in sugar content. There is, however, a slight but discernible difference in the size of chit, or germ, and in a general way the green corn from western seed is slightly coarser in texture and less tender than that from eastern seed. The difference in quality may be accounted for as follows:

The climatic conditions in the western corn-growing sections, especially during the season when corn is earing, are often such as to induce a marvelously rapid development—much more rapid than is often seen in the East. In the West it is sometimes difficult to find ears of sweet corn green enough to be in prime boiling condition in fields where it was equally difficult to find ears which were mature enough to be palatable forty-eight to seventy-two hours earlier. Seed grown under such conditions would often transmit the rapid-maturing habit of the plants that produce it. The quality of green corn, particularly as to tenderness and sweetness, is very dependent upon the stage of maturity at which it is cooked, sometimes the growth of only a few hours affecting the discernible sugar content. If the corn in a field from western seed in which the rapid-maturing habit was transmitted was gathered for canning when most of the ears were in prime green-corn condition, some of the ears would be so mature as to lower the average quality of the pack, but it would be impracticable to reject such slightly overmature ears, and the resulting poor quality of the pack would be charged to generally inferior stock rather than to the effect of the few older ears.

One indication that rapid development, with the consequent short period of prime canning condition, is an important, if not the chief, objection to western-grown seed, is the fact that experienced canners who insist upon eastern-grown seed of the earlier sorts, like Crosby, do not seriously object to well-grown western seed of the later and slower maturing sorts, like Evergreen and Country Gentleman.

Whatever may be the facts as to the relative merits of eastern and western grown seed, the writer believes that it is always true that the character of green corn is more or less affected by that of the soil on which the seed was grown. Seed grown in moderately rich but warm, well-drained, gravelly soils, like those common in Connecticut, New York, Ohio, Michigan, Wisconsin, and some sections of Iowa, Nebraska, and Minnesota, will give better and sweeter corn than seed grown on very rich mucky or prairie soils which would give large crops of field corn. It appears to be impossible to grow on a cold, heavy clay soil sweet-corn seed which will produce green corn of the highest quality.

CROSS-POLLINATION.

The location and character of soil are of less importance in the production of seed corn from which the best results may be expected than that the fields be so situated as to avoid as far as possible liability to mixture through the pollen. This is a far more common cause of inferior quality than is generally supposed. Seed growers object to growing Black Mexican corn because they say it crosses so freely with other sorts. There is no evidence, however, that this variety crosses more readily than others, but when crosses of Black Mexican and other varieties do occur the effects are more readily seen. Instances are known where Moore's Concord was evidently crossed with Black Mexican corn growing nearly two miles away; but in another case, where the Black Mexican and the Moore's Concord varieties were planted side by side on the same day, there was no indication of mixture beyond the sixth row from the dividing line.

Corn pollen in abundance has been obtained from the plumage of a blackbird, which must have flown between 4 and 6 miles from the last field of corn visited, and doubtless others of the large flock to which the bird belonged carried equal quantities of pollen, more or less of which they must have scattered in the field of seed sweet corn in which they alighted.

Difference in season of maturity is not always a protection against crossing. The writer knows of a case in which there was clear evidence of mixture in both directions between Extra Early Red Cory and Stowell's Evergreen corn growing side by side, although the Cory was planted some days before the Evergreen, but in another instance there was no sign of mixture between the Cory and the Black Mexican varieties planted side by side on the same day, all of the silk and the tassels of the Cory being ripe and dry before even the earliest tassel appeared on the Black Mexican, and in this case there were no late-blooming suckers on the Cory to furnish pollen for the earliest Black Mexican plants.

In another instance, where two sorts of corn were separated by a thick grove of tall trees about 4 rods wide, there was no sign of mixture, but just beyond the grove, where the lots of corn were separated by an equal width of grass land, there was abundant evidence of crossing.

In another case, where two sorts were separated by a thick osage hedge not over 12 feet high, there was no indication of crossing within 8 or 10 rods of the hedge, while beyond that distance there were many crosses.

Experience shows that neither a distance less than several miles nor any varietial difference can be relied upon as a certain protection against a mixture of pollen. In most farming regions it is impracticable to locate a field of seed corn so as to guarantee that there shall be no mixture through pollen, though much can be done to lessen the probability of a mixture. How this may be best accomplished is a different problem in each case. Usually the most practical way is to plant each lot of seed as far as possible from any other corn, and also to have as much difference as possible in the dates of ripening of the seed corn and of the corn in the nearest field.

Fortunately, the effect of crossing in corn is rarely masked for a number of generations, as it often is in leguminous plants. It frequently shows so plainly in the grain which is the immediate result of the cross that much of the hybrid corn can be removed by careful sorting before shelling, and it is well to throw out the whole ear rather than to pick out the mixed grain, as is the common practice, because crossing does not always change the appearance of the grain the first season, and there is a strong probability that on an ear on which crossed grains are visible there are other crossed grains which show no external sign of mixture.

CULTURAL METHODS FOR THE PRODUCTION OF SWEET CORN FOR SEED.

In a general way the fertilization and preparation of the soil and the methods of culture which will give the best results with field corn will be equally effective with sweet corn, but because of liability to crossing with volunteer plants it is important that a crop for seed corn should not follow one of any other variety of corn and that care should be taken to prevent bringing into the field viable grains of corn and spores of corn smut or other corn diseases in stable manure or by stock.

Sweet-corn seed is usually of lower vitality than that of field sorts, and planting should be delayed until the soil is well prepared, warm, and dry, special care being taken that the seed is not covered too deep. The small-growing, extra-early sorts, like Cory, Crosby, etc., may be planted in drills as close as 3 feet apart or in hills 3 feet apart each way and so as to secure from four to eight plants to the yard of drill or three or four plants to the hill.

The stronger growing sorts, like Evergreen and Country Gentleman, partly because of their greater liability to abundant suckering, need even more room than most varieties of field corn and should be planted in drills 42 to 60 inches apart or in hills the same distance from each other and so as to secure two or three stalks to the hill or to the yard of drill. Experience has demonstrated that with seed sweet corn equally large yields and better matured seed can be obtained from a somewhat thinner stand than would give the largest yield of field corn.

HARVESTING.

The value of seed corn, especially sweet corn, is largely dependent on the way it is gathered and cured. The average American farmer has drifted into such careless methods of handling corn that it is hard for him to recognize and use the care necessary for the production of good seed. The crop should be harvested as soon as the grain has fully passed into the dough state. The stalks should be cut and put into small shocks, but seed sweet corn can very rarely be well cured in shocks, no matter how small or how carefully they may be set up.

As soon after cutting as the stalks are well wilted, which will usually be in from three to six days, the corn should be husked and put into the drying cribs. It is important, especially with the short-stalked early sorts, that this be done promptly. If allowed to stand long in the shock the stalks will settle so that the ears are likely to come in contact with the soil and the grain be injured in appearance and viability.

Some growers, particularly those of Connecticut and Ohio, do not put the stalks into shocks, but go through and "top" or remove the part above the ear, and sometimes slip down the husk so as to fully expose the grain to the sun and wind, when it will dry out very rapidly and perfectly and can be gathered from the standing stalk. A disadvantage of this method is that if such "stripped" corn is exposed to even a slight frost before it is quite dry its viability as well as its vitality is lessened, often entirely destroyed.

In the Western States there is usually so little rain and such high dry winds are prevalent during the autumn months that harvesting can often be safely delayed until the corn is nearly cured in the field on the still standing stalks, and then the corn can be gathered directly into large cribs to complete the drying; but even here early husking and cribbing are desirable.

The best way to handle sweet corn in the field is to husk into baskets or crates, as there is liability to serious injury by dirt, showers, or breaking of the skin if the ears are thrown on the ground or into a wagon, and if this occurs while some of the grains are still in the milk they will become discolored and so injure the appearance of the lot of seed as to render it unsalable.

CURING AND DRYING.

The essentials to the proper curing of sweet corn are that each and every ear shall be exposed to circulating air until the grain is perfectly dry and that this be accomplished without exposure, even for a few hours, to a temperature below 34° or 36° F. The vitality of green corn while it is still in the milk or dough state will be destroyed by long exposure to a low temperature, even if it be one several degrees above the freezing point, but as the grain matures and dries out it will endure lower temperatures without serious injury,

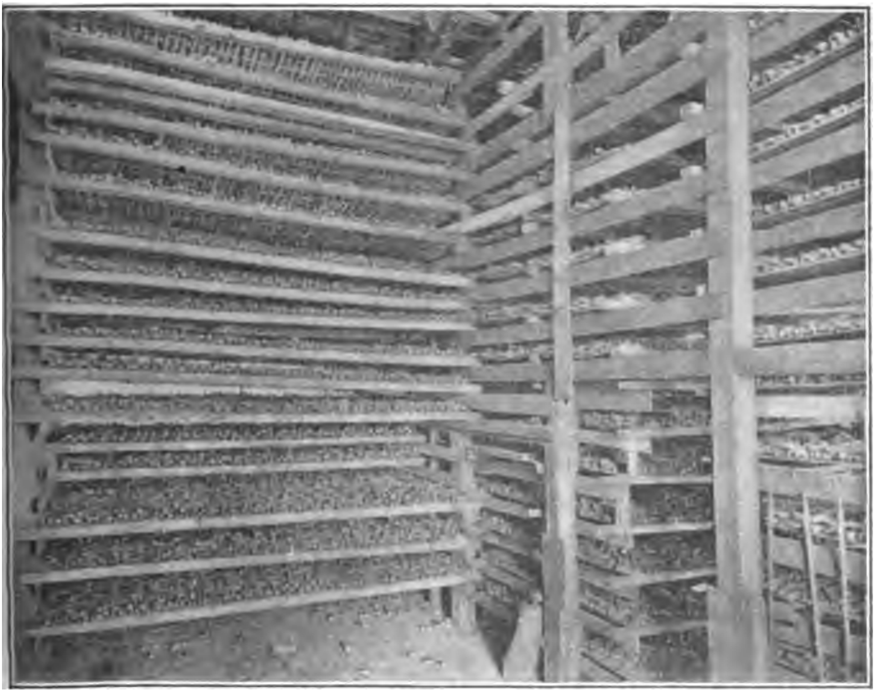

FIG. 1.—Ears of sweet corn on drying racks.

although long exposure to temperatures much below 32° F. lessens its vitality.

One of the best and safest ways to cure seed corn is that commonly practiced by the New England growers, the corn being spread in open sheds or barns on scaffolds formed of rails or slats so placed as to allow the air to pass freely between them. The corn should be spread very thinly at first—not more than two or three ears deep—or, better still, in a single layer, but it may be piled deeper as it dries out, care being taken not to do this until the corn is so dry that it will not mold. (See fig. 1.)

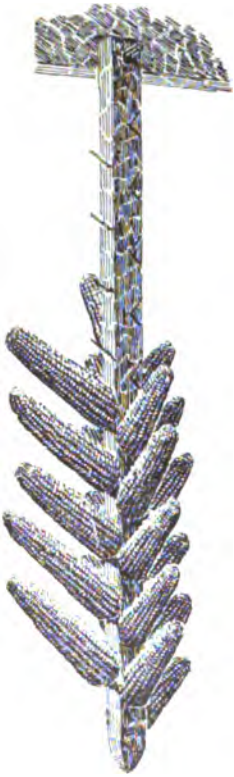

FIG. 2.—Ears of sweet corn on drying sticks.

A second method of curing seed corn is by the use of drying sticks about 1 by 2 or 3 inches and about 4 feet long. Old fence pickets are often used for this purpose. They are prepared as follows: Bore a half-inch hole about 2 inches from the end, and drive into each of the four sides of the stick, about 3 inches apart, a series of eightpenny or tenpenny round-headed wire nails, so that they will enter the wood about ¾ inch and project at a uniform angle of between 15 and 20° toward the end of the stick having the hole. On each nail jam the butt of an ear of corn so that the ears stand out in four directions from the sticks, which should then be hung on nails in the rafters of a low, open shed or on scantling placed at proper distances apart in such a building as a tobacco shed. It takes some time to stick the ears on the nails, but when this is done the corn can be well cured with little further attention. (See fig. 2.)

A third method is to husk into lath crates holding from 1 to 2 bushels of ears, and stack these crates either in the field, well protected from rain, or on the floor of barns where there is a full circulation of air. In either case the crates should be so stacked that the wind can pass freely through and between them.

A fourth method, requiring fewer special facilities but greater care, is to put the corn into rail or slat cribs built quite open and not over 20 to 30 inches wide at the bottom, but wider at the top. In filling these cribs, spread the corn to a depth of from 12 to 18 inches, and then place a series of slats about 2 feet apart across the crib and just above though not resting on the corn, being fully supported by the sides of the crib. Fill in 12 to 18 inches of corn above these slats; then place a second layer of slats in the same way, but so as to break joints with the first layer, and repeat until the crib is full.

These slats are to prevent the corn settling together so as to hinder the free access of air. The cobs of sweet corn are not so stiff as those of the field varieties, and if green or partially dried ears are piled without support they will, even in a very narrow crib, settle together so as to prevent thorough drying.

Seed sweet corn can be cured so as to obtain a fine crop of high viability by any of the preceding or similar methods, but it is essential that the work be done promptly, so as to take advantage of bright weather and secure the thorough drying out of the corn before it is exposed to continuous damp or freezing weather. It is rarely possible to secure a good lot of seed of high viability if the work of curing is delayed until after the season when favorable weather conditions can be expected.

It is possible to cure corn by artificial heat, but this requires the most skillful use of warmed—not hot—air, kept in constant motion. Even with these precautions there is always a liability of the corn being ruined for seed purposes by mold, rot, or overheating, and for these reasons the method is not recommended.

As soon as the corn is perfectly dry it may be shelled, though it will generally keep much better on the cob. In a temperature below freezing, corn, either on the ear or shelled, will seem to be dry when it is not. Before shelling, it is therefore well to make a test sample of a quart or more, composed of a few grains from a great number of representative ears. If this, after standing for a day or two in a temperature considerably above freezing, becomes soft and damp, the shelling should be delayed until the corn is quite dry.

Well-cured corn is easily shelled by machine, by flails, or by hand, and the grain should be immediately run through a fanning mill, when it may be sacked, but it should be closely watched, and if it does not remain perfectly dry in a temperature above freezing it should be again fanned and spread to dry, and this process repeated on the least indication of the presence of moisture.

In order to produce good sweet-corn seed one must be prompt to cut it when ripe, husk it as early as possible, and immediately get it under shelter where it will be exposed to every wind that blows until it is thoroughly dry, using every hour of bright sunshine in order to accomplish this before freezing weather.

AVERAGE YIELD OBTAINED AND PRICES PAID.

The return of usable seed varies greatly, and is affected not only by the variety and the weather, soil, and cultural conditions, but by the care with which the crop is gathered and cured. A seedsman to whom a surplus is not objectionable will contract on a basis of 5 or 6 acres of the earlier, lighter-yielding sorts and 3 or 4 acres of the larger kinds per 100 bushels wanted; but one to whom a shortage is preferable to a surplus will limit his contracts to 3 or 4 acres of the earlier and 2 or 3 acres of the larger sorts per 100 bushels wanted. In both cases allowance is made for the liability of total failure of some of the crops.

The prices paid for growing vary greatly with the season, being much lower after seven fat years than after seven lean ones; at present they range from 70 cents to $1.15 a bushel of 50 pounds for the easier grown sorts, and from $1.10 to $1.50 for the lighter-yielding sorts and for those requiring greater care in curing.

UNIT OF MEASUREMENT.

Although contracts are sometimes made per 100 pounds, the more common unit is the "struck bushel," which is assumed to weigh 50 pounds; but the actual quantity which the term stands for varies greatly, not only with the sort, but with the condition and character of both the stock and the sample, and ranges from as low as 37 pounds in a very dry sample of a choice stock of Evergreen or Country Gentleman corn to 53 to 56 pounds in a poorly cured sample of the Minnesota variety.

MINIMUM ACCEPTABLE VIABILITY.

The minimum percentage of viability accepted by seedsmen on growing contracts ranges from 75 to 85 in years of scarcity to 90 or even 95 in years of plenty. There is some excuse for this variation in the fact that corn of low viability at harvest often deteriorates quite rapidly and is practically worthless the second year, while that of high viability kept under favorable storage conditions will germinate nearly as well the second or even the third or the fourth year as the first, and in a short year there is little likelihood of the necessity of carrying over stock, while it is probable that a part at least of the crop in a full year will have to be carried until the next season. Seedsmen often claim the right to purchase, at a reduction in price corresponding to its inferiority, a crop of seed grown under contract which is below acceptable viability or which is so imperfectly cleaned as not to be suitable for seed.

GROWING STOCK SEED OF SWEET CORN.

The structure of the floral organs of the corn plant is such as to secure under normal conditions more or less complete cross-fertilization, and it has been found that there is liability to rapid loss of vegetative vigor in plants which are persistently self-fertilized. This, in connection with the fact that it is difficult, if not impossible, under ordinary farm conditions to prevent more or less cross-pollination, leads to methods and practices in growing stock seed corn which differ materially from those that give the best results with most vegetables. Instead of trying to isolate the stock blocks, it is suggested that they be located near the center of the largest available field of the variety and that the selection of breeding stock be made as follows:

First, formulate a very clear conception of precisely what an ideal plant of the sort to be grown should be, not only as to grain and ear, but as to stalk, leaf, husk, silk, and tassel, for this is essential to the raising of the best seed of the sort. With this conception in mind or, what is far better, clearly written out and illustrated by photograph, go into a field of the sort at the time the plants are coming into silk and mark with a string, or a bit of cloth, or in some way a number of stalks. It is wise to select at least a hundred plants which are as nearly alike and typical of the sort as can be found.

When the grain is in the dough state, assemble the marked stalks and, after stripping down the husks, very carefully select and tag those in which the ear and the grain are nearest to the ideal. The ears from each of these selected plants should be carefully numbered, dried, and stored. The next spring mark out, near the center of the largest available field of the sort, a block of 4, 9, or 16 square rods for each of the selected ears, and plant each block with seed from one of the selected plants.

It is wise in making the planting to reserve at least one-fifth of the seed on each ear, not only for replanting if necessary, but so that reference may be made to the exact character of the parent stock. When the corn is coming into silk, carefully go over the blocks and select those in which the plants in stalk, leaf, husk, silk, and tassel are most uniformly of the desired character, rejecting the plants which show the greatest variation, even if some of them, as will in all probability be the case, are among the most perfect plants in the field.

When the corn is passing into the dough state go over the selected blocks and, stripping down the husks, select the blocks in which the ears are most uniformly of the desired varietal character, rejecting as in the selection of the individual plants, all the ears, no matter how perfect they may be, from the blocks showing greatest variation. As a rule it will be best to select several blocks in order to avoid the loss in vegetative vigor which in the corn plant often follows too close breeding.

From the chosen blocks select a number of the most perfect ears, to be tagged, numbered, kept separate, and again planted in separate blocks the next season. The balance of the corn from the selected blocks can be gathered and the better ears bulked and used the following season for planting the field in which the seed blocks are to be located.

Working in this way, never losing sight of or changing the ideal varietal characteristics of the sort, always selecting from the most uniform lot, resisting the temptation to use an exceptionally perfect ear found in a variable block, one can in a few years establish strains which will be greatly superior in practical value to most of the seed now used.

THE GROWING OF GARDEN BEANS FOR SEED.

The bean plant, particularly if it be one of our garden varieties, is exceedingly sensitive to unfavorable conditions of heat and moisture. If the soil is damp, but not quite moist enough to secure good germination, the seed will "malt" or sprout and die; if it is only a little too wet the seed will germinate, but die without expanding its true leaves.

Young bean plants would be killed or permanently dwarfed by a drenching rain which would have no permanent effect upon a young plant of corn. If when the plants are in flower the supply of moisture is shortened, either by drought or by injury to the roots through too close or too deep cultivation, so that the plants wilt, be it ever so little, the pods will fail to fill, and it is very seldom that the later-maturing pods on the plant will be any better, even if more favorable conditions bring out an abundant bloom.

From the starting of the seed into growth to the storage of the ripened grain, beans are exceedingly sensitive to unfavorable conditions of moisture. In spite of this, seed beans will often prove a profitable farm crop on good land anywhere in the United States north of latitude 40° or 41° and east of the Dakotas. South of latitude 41° beans are so liable to injury by the bean weevil, and in much of the country west of central Wisconsin the crop is so likely to be cut off by dry, hot winds at the time the plants are in flower, that seed beans are rarely profitable for many successive seasons, though some very fine crops of seed beans have been grown in Minnesota and the Dakotas.

LIMA AND POLE BEANS.

Seed of Lima beans, as well as of pole varieties of garden beans, can be very profitably grown along the western coast of California, where the night winds from the ocean furnish the necessary moisture and the crop seldom suffers from drenching rains. Of late years seed of garden bush beans has also been grown to some extent in northern California, where there is less liability to disease than in the bean-growing sections of the East, but, in general, California crops are grown on farms wholly devoted to growing seed rather than as a part of the regular rotation of mixed farming.

GARDEN BEANS.

Garden beans have developed into many quite distinct varieties adapted to different soils, and it is quite essential to their profitable culture as a seed crop that one plant the sorts best suited to his particular soil conditions. This can only be learned through test plantings of the different sorts.

It will generally be found that varieties with thick, fleshy pods, like the Valentine, do best on rich clay soils and are apt to fail on light sandy ones, where such sorts as the Long Yellow, which rarely succeeds on clay soil, would give their best crops. Generally the large, wax-podded sorts, like Kidney Wax, give their best returns on rich black lands, where the flat, green-podded sorts would be apt to "run to vine," with small return of seed. Most of the wax-podded sorts, particularly those with fleshy pods, require rich, strong, moist soils, while the smaller, flat, green-podded sorts will often give good returns on light, warm, sandy soils on which other kinds would do poorly.

SOIL AND CLIMATE.

Conditions of soil and climate often greatly modify the character of bean plants, particularly as to the size and smoothness of the leaves and the size, fleshiness, and color of the green pods and beans. The relative size and color of the dry seed are very largely affected by the climatic conditions at the time of ripening, but differences in these respects, even when they are continued for several seasons, are not transmitted in any appreciable degree through the seed.

Lima and other pole beans grown without poles in southern California for many generations take to poles as well and mature as early as the same sorts grown on poles in Connecticut. Certain diseases, such as anthracnose and rust, are often carried in the seed, and there is great practical advantage in the use of seed which is the product of healthy plants.

LOCATION OF BEAN CROPS FOR SEED.

The structure of the flowers of the bean seems to guard against cross-pollination as effectually as that of the flowers of the corn plant provides for it, and seedsmen do not generally ask that growers shall isolate fields of different varieties, though they often insist that crops of different sorts shall be stored and handled in separate buildings.

The cultural methods which will give the best crop of seed beans do not differ materially from those used in growing beans for commercial purposes, and these methods have been so well and fully stated in Farmers' Bulletin 289 that it is useless to repeat them here. It may be well, however, to refer to some minor differences in cultural methods and requirements.

No matter how well founded may be the claim of some bean growers that with commercial beans greater profit will come from heavy seeding, certainly better seed beans can be grown by light seeding. There is a great difference in the quantity of seed needed with different varieties, 8 to 12 quarts to the acre being as liberal a seeding for a small-seeded but large-vined sort, like the Crystal White Wax, as a full bushel would be for some of the larger varieties, like the Flageolet. The cost of growing seed beans is somewhat increased by the work of "roguing" out the mixed and inferior plants, but when good stock seed is used there should not be more than one "rogue" plant to every 10 or 20 rods of drill; often there will not be more than one to 50 or 100 rods.

Many sorts of garden beans can be grown, gathered, thrashed, and fitted for market at less cost than field beans, and they generally yield fully as much to the acre; but other sorts, particularly some of the large, fleshy, wax-podded varieties, require richer soil and a great deal more care in curing and thrashing, and they generally yield less to the acre.

The labor necessary to thrash and clean seed beans is largely governed by weather conditions at the time of harvest. The appearance of the sample is very dependent upon the skill of the thrasher. The lot secured by one man will contain so many split beans, and those covered with sections of pods, that it can not profitably be made fit for seedsmen's use, while another man with the same machine will secure a fairly clean lot from the same crop. The labor and skill necessary to obtain a good result are also quite dependent upon the variety.

The pods of some of the very fleshy, wax-podded sorts shrink down about the beans and in thrashing break so as to leave many of the beans incased in sections of the pod. It is sometimes necessary to run the seed of such sorts through a "rubber" made of a cylinder, with many teeth about one-fourth of an inch long and three-eighths of an inch in diameter, revolving comparatively slowly against concaves covered with ribbed rubber or very coarse, heavy canvas. On account of the difficulty in growing and thrashing some varieties, seedsmen should, and commonly do, make a difference in the prices paid, though often this difference is not sufficient to balance the actual difference in the cost of growing, thrashing, and recleaning.

YIELD PER ACRE AND PRICES PAID.

As with sweet corn, the yield varies greatly with the variety, season, soil, and the skill and carefulness of the grower. It ranges from 10 to 30 bushels per acre, with phenomenal yields up to 40 or even 60 bushels, a yield of 10 bushels being comparable as to quantity with one of 18 to 20 bushels of wheat. Seedsmen generally base the area contracted for on a yield of 8 to 12 bushels to the acre.

The prices paid farmers for growing beans vary with the season and are more influenced by the ruling prices for commercial beans than is the case with corn. At present they range from $1.30 to $2.30 a bushel for the sorts which are most easily grown and thrashed, and from $1.50 to $2.50 for those which require greater care and labor. Prices for growing Lima and pole beans range from $2.75 to $4 a bushel.

UNIT OF MEASUREMENT.

The unit of measurement in farmers' contracts for growing beans is usually a nominal bushel of sufficient weight to leave 60 pounds after all cleaning and hand picking necessary to make the beans fit for seedsmen's use. There is, however, a difference, sometimes amounting to from 5 to 10 per cent, in the actual weight of the same bulk of equally clean and well-cured lots of different varieties.

MINIMUM ACCEPTABLE VIABILITY.

The minimum percentage of viability accepted by seedsmen on growing contracts varies somewhat in different seasons and with different varieties of beans, and runs from 80 to 95 per cent. There is less excuse for variation in the percentage of acceptable viability with beans than with corn, for beans usually grow as well the second season as the first, and a large proportion of the beans which are not viable will be removed in hand cleaning.

Their appearance is an important factor in determining the acceptability of beans, and any distinct stain or discoloration on as many as 8 or 10 per cent of the beans justifies their rejection, even if they be of high viability. Seedsmen claim the right to purchase, at an equitable reduction in price, beans grown under contract which from discoloration or want of viability are not acceptable on the terms of the contract.

GROWING STOCK SEED OF GARDEN BEANS.

In growing stock seed of garden beans, even more than with corn, the first requisite is a very clear conception of what constitutes an ideal plant of the sort, and this should extend to all of its parts, for very often the first indication of an accidental crossing which will ultimately ruin the stock is in some slight change of no economic importance. In the bean plant the result of crossing is seldom seen in the seed, and sometimes is not noticeable in any part of the plants which are the immediate product of the cross. Generally, crossing is first manifested in some inconspicuous way, such as in the size or the color of the flower, in the form or the tint of the marking of the seed, or in the shape or the color of the point of the pod; but these are premonitions of changes in subsequent generations which will render the stock worthless and which it will be practically impossible to eradicate by the most careful roguing.

In starting a foundation stock one should most carefully select a few plants which in habit of growth, in leaf, flower, pod, and in every way are of the exact varietal character wanted. The seed of these selections may with reasonable safety be planted side by side, but each plant should be carefully examined, and the whole of any lot in which a single plant shows variation that seems to have come through the seed rather than as a result of more or less perfect development should be rejected, and it is often wise to reject all of the stock that traces to the same original selected plant. In making such rejections it is very important that one should distinguish between variations which were transmitted through the seed and those which result from conditions of growth and which would not be carried in the seed. This will call for the exercise of wise judgment founded on a full and accurate knowledge of the varietal characteristics of the sort. It will be seen that in spite of the lesser liability to cross-fertilization, the building up of a true stock is a much slower process with beans than with corn, but when one which is true has been secured it is much easier to keep it so.

THE GROWING OF GARDEN PEAS FOR SEED.

Peas are closely related to beans botanically, and the general climatic and soil conditions requisite for the best development of the two are very similar. Peas require for their most profitable development a cool, moist climate, and they can not be profitably grown in a hot, dry one or where there is a liability of such conditions occurring for even a few consecutive days. Clear, bright weather free from drenching rains is essential to the ripening and curing of the seed. It not infrequently happens that because of wet and catchy weather at harvest time the seedsman fails to get any usable seed from fields of peas which had given promise of a large yield.

The sections where seed peas can be profitably grown are still further limited by liability to injury from the pea weevil. Injury from this insect is less common north of latitude 42° to 43° than farther south, and crops grown on clay soils, particularly if they be near large bodies of water, suffer less than those grown on sandy soils. For these reasons the growing of seed peas in America is generally confined to the sections bordering on the Great Lakes and to a few locations in Washington, Oregon, and northern California where the climatic conditions are favorable.

There is no garden vegetable in which uniformity in habit of growth and in the maturing of the fruit in all the plants of a culture[a] is of greater importance than with green peas. The character of the plant and the cultural methods commonly employed in growing it are such that the gathering of the first one or two pickings of green pods is likely to so check the growth of the plants that the later maturing pods are decidedly injured, often so much so as to make the picking of them for culinary uses unprofitable. Again, the good appearance of the pods in the basket is very dependent upon evenness of form and maturity, a comparatively slight difference in the form or the age of a few pods ruining the effect of the whole. Lastly, any overripe or "off-colored" pea is made more conspicuous and objectionable by cooking.

For these reasons, evenness in size of plant and in date of maturing is a more important element of value in garden peas than in most other vegetables.

CULTURAL REQUIREMENTS.

The pea plant, like that of the bean, is very materially influenced as to habit of growth and maturity by soil conditions, and in the pea changes due to this cause are transmitted through the seed seemingly with cumulative force. It is consequently very important that all of the plants of a "culture" for seed should be as nearly uniform in size and maturity as possible. Often a field which has been recently cleaned of forest or one which has been heavily manured will yield a large crop of seed, which, however, will not be of the best quality because of lack of uniformity in the size and in the earliness of the producing plants.

The best crops of seed peas, as regards both quality and quantity, can usually be grown by turning under old timothy sod on a uniform, well-drained, clay or clay-loam soil. Uniformity in character of the soil on which the crop is to be grown is not of greater importance than that its preparation should be such as to put it into good tilth and to make it as even and uniform in composition and physical condition as possible, and the seed should be so planted as to secure evenness in germination and in the growth of the young plants.

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[a] A single planting of the same sort.

No plant responds more readily to good preparation and culture of the soil than the pea, but its habit of growth and the cultural methods used are such that thorough preparation should be given before the seed is put in the ground.

Not only the growth of the plant but the harvesting of the crop in good condition is very dependent upon favorable weather, and in most sections of this country where seed peas are largely grown there is much more likelihood of the early-planted crops escaping unfavorable conditions than those which are planted later. It is therefore very desirable that the seed should be sown as early as the ground can be put into good condition, and it will generally be desirable that the field, particularly if it be in sod, be plowed in late fall or early winter, which would have the further advantage of destroying many cutworms and other injurious insects. The ground should be worked and the seed sown as early in the spring as possible, but one should not permit the desirability of early planting to tempt him to sow before the ground has had the best possible preparation.

QUANTITY OF SEED TO USE PER ACRE.

The quantity of seed to use to the acre will depend upon the variety and, in some cases, upon the soil and location. There is a great difference of opinion as to the quantity of seed which will give the most profitable returns, and that recommended varies from 80 to 160 pounds for such small-seeded, large-vined sorts as the Admiral, and from 120 to 180 pounds for the larger-seeded, short-vined kinds like the Yorkshire Hero. The writer believes that the best seed can be grown by comparatively thin seeding.

In some sections of the country, from Dakota westward, pea vines show a much greater tendency to branch from the bottom than the same stocks would if planted in the East, so that in Washington and California as good results can often be secured from the use of only 20 to 40 pounds of seed as from the larger quantities that eastern growers think it necessary to use.

Great care should be taken to secure even distribution and covering of the seed. This can generally be accomplished best by the use of some form of grain drill, but care should be taken to select one that will not crack the seed. It will often be desirable after sowing to run over the field with a light slanting-tooth harrow, but if this is done it should be so timed as to avoid either uncovering the seed or injuring the germinating plants.

ROGUING.

While experience has demonstrated that it is practically impossible to materially improve a stock of peas by roguing, this method is often resorted to by many growers in order to secure so-called pure stock. Roguing is of less value with peas than with beans, because the greater number of plants to the acre and the irregularity of arrangement and growth make it a practical impossibility to critically examine every plant, or even a large proportion of the plants of a field, and very often a crossed or " off " plant can not be distinguished even by careful examination, yet the seed of that plant may the next season develop into plants which are very objectionable. Again, there is always a possibility, it might even be said a probability, that the blossoms of a plant so conspicuously " off " that the roguer sees and removes it had already contaminated from one to a score or more of the surrounding plants, so that their product would be seriously " off " the next season.

In practice, the most that one can hope to accomplish by roguing seed peas is to prevent the stock from deteriorating still further, the only hope of securing a pure or improved stock being in selecting and breeding from the best rather than in eliminating the poorest.

While roguing should not be depended upon, especially for the growing of stock seed, it should not be neglected. The fields should be carefully gone over at the time when the earliest plants are passing out of bloom. Each man should take a strip of a certain width and, moving with his back to the sun, confine his attention to that strip, removing all of the rogues seen there and resisting the temptation to go foraging to the right or the left; and he should return over the same strip, scanning it as carefully as at first, for very often a rogue which was not noticeable when looking with the sun is very evident when looking in the opposite direction.

GATHERING AND CURING.

The commercial value of seed of garden peas is largely influenced by the appearance of the seed, and this is very dependent upon the conditions and the care used at the time of harvest. With many sorts it is desirable that the seed should retain a green shade, and that it may do so, as well as to prevent loss from shelling, the vines should be gathered as soon as the bulk of the crop is hard and before any of the ripest pods begin to shell or have been bleached by the sun.

The best plan of harvesting will depend upon the variety grown, the weather conditions, and the kind of labor, and of farm machinery available. Where the low-priced labor of women and boys can be obtained, the very dwarf sorts, like American Wonder, can often be most economically gathered by hand into bunches of 2 to 4 cubic feet. The next larger-sized sorts can be gathered with a sharp hoe, a short scythe, or a pea rake (see fig. 3) into bunches of about the same size. The larger-vined sorts can be "rolled" into bunches of 4 to 8 cubic feet with a short scythe or cut with a mower carrying "pea guards" on the cutting bar, so as to raise the vines and prevent cutting the pods, and then be gathered into windrows or bunches.

While in the field, the bunches should be turned every two or three days and after every rain, in order to hasten the curing and to prevent the rotting or the bleaching of the seed. In order to avoid loss of color or injury from rain, it is desirable that the vines be well stacked or put into barns as soon as they are so dry that they will not mold or spoil in the mow. The vines should remain in the mow until they are well cured and can be easily and conveniently thrashed.

The smaller-vined sorts can usually be thrashed most economically by flails. The larger-vined varieties are best thrashed by an ordinary bean thrasher with part of the concave teeth removed, but it should be so managed and run as to prevent splitting the peas. Skillful handling of the thrasher is quite as important with peas as with beans.

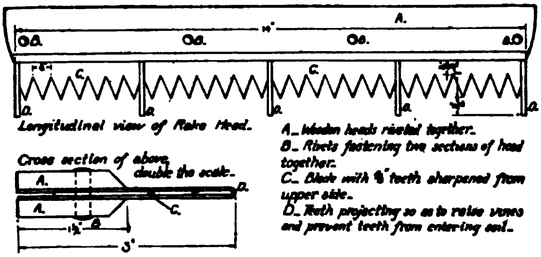
A.
14"
a
C.
a
Longitudinal view of Rake Head.
Cross section of above, double the scale.
A.
A.
D.
C.
B
1½"
3"
A. Wooden heads riveted together.
B. Rivets fastening two sections of head together.
C. Blade with ⅛" teeth sharpened from upper side.
D. Teeth projecting so as to raise vines and prevent teeth from entering soil.

FIG. 3.—Sketch of head of pea rake for gathering short-vined peas.

YIELD TO THE ACRE.

The yield of salable seed peas is very dependent not only upon the crop grown but upon the proportion of it one can secure in salable condition. It often happens that through a little delay in harvesting from 10 to 40 per cent of the seed is lost through shelling in the field. Again, a few days of rainy weather may cause the loss of even the entire crop through sprouting and rotting in the field. Lastly, there may be a very heavy loss through the splitting of the seed in thrashing. The yield also varies greatly with the variety.

Under favorable conditions one may hope to harvest from 10 to 30 bushels to the acre, and the most productive sorts may yield up to 60 bushels under favorable conditions. Seedsmen generally contract on basis of a return of from five to eight times the quantity of seed planted, this basis allowing for the total failure of some of the plantings.

PRICES PAID.

The prices paid for growing seed peas vary greatly with the variety and run from 70 to 95 cents a bushel for some of the easiest grown sorts after a few years of full crops to $1.75 to $2.50 for the dwarfer vined and less productive sorts after a few seasons of light yields.

UNIT OF MEASUREMENT.

The common unit of measurement for peas is the same as for beans, i. e., a "bushel" of sufficient weight to leave 60 pounds after the necessary cleaning and hand picking. There is a greater difference in the weight of the same bulk of different varieties of peas than of beans. Some of the wrinkled sorts weigh only 50 pounds to the bushel, while the smaller, smooth sorts weigh from 58 to 64 pounds. Clean, bright seed is desirable, but it is not so essential as with beans. Any conspicuous injury from the pea weevil or other insects or any discoloration or splitting of the skins in the field or of the grains in thrashing is regarded as justifying the rejection of the crop as not suitable for seedsmen's use.

MINIMUM ACCEPTABLE VIABILITY.

Seedsmen seldom are obliged to reject because of poor germination, otherwise acceptable lots of peas grown on contract. A properly-cleaned sample will rarely show less than 85 or 90 per cent of viability shortly after harvest, though where the plants have been seriously injured by lice or in some other way the seed sometimes loses in viability quite rapidly.

GROWING STOCK SEED OF PEAS.

Stock seed of peas should be selected and grown in the same way as that recommended for beans. With peas, however, variations due to soil and cultural conditions are transmitted through the seeds, so that care should be taken to grow stock to be used for seed on soils which are uniformly favorable for the best development of the particular variety. Peas are also more liable than beans to crossing through the action of wind or of insects, and for this reason it is not wise to grow stocks of different sorts side by side. They should be either isolated or located in a field of the purest available stock of the variety.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 185.
B. T. GALLOWAY, *Chief of Bureau.*

COLD RESISTANCE OF ALFALFA AND SOME FACTORS INFLUENCING IT.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 6, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Cold Resistance of Alfalfa and Some Factors Influencing It." This report was prepared by Mr. Charles J. Brand while Physiologist in Charge of Clover and Alfalfa Investigations in the Office of Crop Physiology and Breeding Investigations, and by Mr. L. R. Waldron, superintendent of the subexperiment station conducted by the State of North Dakota at Dickinson. I recommend that it be published as Bulletin No. 185 of the special series of this Bureau.

One of the important lines of investigation in the Bureau of Plant Industry is the determination of the factors that make it possible for plants to thrive in the extremely cold sections of the West and Northwest. It is a broad, complicated question, and all of the factors can be determined only by studies that extend through many winters of extreme cold. One such season, the winter of 1908–9, occurred during the progress of the studies of the writers and forms the basis of the principal part of the discussion. The investigations reported, however, have been in progress for five years in different parts of the Northwest. They include 80 different kinds of alfalfa, many of which are introductions of this Bureau.

It would have been desirable for the observations of the writers to have extended over a greater number of severe winters. The need of information on the part of those in the cold regions is so pressing, however, that it seems advisable to present the facts contained in the paper as a contribution to the comprehensive series of similar studies in progress in the Bureau. The deductions of the writers are especially helpful in suggesting lines of investigation that are likely to be developed further by investigators in the cold regions, as well as by those within the Bureau. Another phase of alfalfa hardiness has already been discussed in Bulletin No. 169 of this Bureau, entitled "Variegated Alfalfa," by Mr. J. M. Westgate.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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. P. I.—579.

COLD RESISTANCE OF ALFALFA AND SOME FACTORS INFLUENCING IT.

INTRODUCTION.

Interest in the culture of alfalfa continues to increase. As a wealth producer this crop is winning for itself a predominant place in the agriculture of the world. While in some parts of Europe it can no onger be grown with the old-time success, and serious people are discussing measures for bringing its culture back to a paying basis, the United States has as yet developed only a small fraction of its alfalfa possibilities.

So far as the northern part of the Great Plains area is concerned the investigations reported upon in the present paper show that weather, tillage, and the use of a suitable strain of seed are the controlling factors in successful alfalfa production when soils of average fertility are employed. Snow covering and the presence or absence of excess moisture in the soil were found to be fully as important in winterkilling as minimum temperatures; differences in tillage and in the previous treatment of the land had profound effects, and finally the greatest possible diversity was found in the endurance shown by strains of seed from different parts of the world.

PURPOSE OF THE INVESTIGATIONS.

In the autumn of 1904 the Bureau of Plant Industry began a comprehensive study of the alfalfa plant. During the preceding years many new strains had been introduced[a] with a view to finding better kinds for our older alfalfa-producing areas and also sorts that would succeed in areas where the ordinary strain had failed to establish itself.

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[a] During the period that elapsed from May, 1898, until November, 1904, the Office of Foreign Seed and Plant Introduction of the Department of Agriculture introduced a total of forty-two strains of alfalfa from different parts of the world. Included among these earlier importations were the following: Fifteen numbers secured by Professor Hansen in Turkestan which constituted what was, so far as we know, the original introduction into North America of the form of alfalfa grown in that country; four numbers sent in by Mr. Swingle, including the well-known Provence and Poitou strains, also what was probably the Department's first introduction of the so-called commercial sand lucern, from France, and the highly prized Oasis alfalfa of the Sahara from the Oued Rirh; three interesting Algerian strains grown in the province of Constantine, secured by Messrs. Fairchild and Scofield, including the interesting form

Little was known as to how these new plant immigrants would behave in their new surroundings, and as their number grew it became very apparent that there was acute need for information as to what factors governed their successful growth. Without this knowledge the most effective distribution in this country was impossible; hence the investigations begun in 1904 were planned with a view to satisfying this need.

The many forms of alfalfa secured by the Bureau of Plant Industry have now been grown or are being grown in groups of from 2 to more than 200 in several hundred places scattered over the country. These different localities represent in a very full measure the great diversity of climate and soil present in the United States and furnish an opportunity for studying and comparing the behavior of the various kinds of alfalfa under a great range of conditions.

Throughout the southwestern portion of the United States and in practically all areas where irrigation is practiced farmers have had very little difficulty in securing and maintaining highly profitable stands of alfalfa, but up to the present time Kansas and Nebraska are the only States that have made a notable success in growing this crop without irrigation. The alfalfa, or lucern,[a] grown in these States

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grown in rows by Mr. G. Ryf, of Setif (see Fairchild, Bulletin 72, pt. 1, Bureau of Plant Industry, U. S. Dept. of Agriculture), a sample of the so-called sand lucern, and the variety known to botanists as *Medicago sativa gaetula*; two numbers from Peru, two from Argentina, and two from Arabia, secured by Messrs. Lathrop and Fairchild; one from Egypt, from Mr. Fairchild; two numbers constituting a new introduction of the Oasis alfalfa, sent by Mr. Kearney from the Oasis of Tuggurt in Algeria; seven new lots from various parts of Turkestan, secured by Mr. Bessey; a commercial importation from Turkestan; two strains from Mexico, and the interesting Peruvian alfalfa described in Bulletin 118 of this Bureau (see Brand, "Peruvian Alfalfa," Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture).

Since the autumn of 1904 nearly two hundred numbers have been introduced from various parts of the world; in addition a large number of more or less distinct strains have been secured from various parts of the United States, and a still larger number have been secured by propagation of seed from previous introductions. All of these domestic and foreign races and their progeny constitute the richest material for the study and breeding of alfalfa that has ever been brought together.

[a] Alfalfa and lucern are wholly synonymous common names for *Medica sativa* (L.) Mill. [See Scofield, Carl S., "The Botanical History and Classification of Alfalfa," Bulletin 131, pt. 2, Bureau of Plant Industry, U. S. Dept. of Agriculture.] The former is used in practically all Spanish-speaking countries and countries that drew their original supplies of seed directly or indirectly from Spain. This includes nearly all of the western continent. The name "lucern," on the other hand, is the name generally applied in Germany, France, and contiguous countries. It is also the name commonly used by the Mormon farmers of Utah. The common name used in Italy is "herba medica."

came from California and Utah and is probably descended from the Chilean alfalfa introduced into this country about 1855. In a little more than a half century, so readily adaptable is alfalfa, this strain has spread over the agricultural areas of the greater portion of the western half of the United States, where it constitutes the backbone of agriculture. This strain, in the form to which it was unconsciously modified as it moved eastward, has been found hardy in Colorado, Kansas, Wyoming, south of the middle line of Nebraska, and by continued growth has been extended throughout Nebraska and in Montana as far north as the valley of the Milk River in the northern part of the State.

In Kansas, farmers who have been growing alfalfa for from twenty to twenty-five years state that the sort they have used has never winterkilled to a noticeable extent.

Speaking broadly, there are three great areas for which no well-adapted alfalfa has been available in quantity: (1) The humid Eastern and Southern States; (2) the semiarid regions where irrigation water is not available, including especially the drier parts of the Great Plains and Intermountain areas, and (3) the cold northern part of the country.

In the region north of the Valley of the Platte in Nebraska and extending eastward to the Atlantic Ocean none of the strains of alfalfa, either of Chilean or European origin, obtainable in commercial quantities have proved hardy in the sense that they can be absolutely depended upon. Hence, one of the great needs of our northern agriculture and that of Canada has been an alfalfa that is perfectly hardy and reliable in this area.

It is the purpose of the present paper to discuss rather fully some of the factors that appear to be important in the wintering over and winterkilling of alfalfa. The greater part of this work has been done in North Dakota at the Dickinson subexperiment station, but advantage has also been taken of using, for collateral observations, numerous other experiments located in various parts of the West, North, and Northwest.

Dickinson is located in the western part of North Dakota at an altitude of 2,453 feet. The range of temperature thus far recorded is from −47° to 110° F. The winters are severe on plant life. The soil is similar to that of much of the Great Plains area. An alfalfa that does well at Dickinson is likely to succeed in a large part of the surrounding region.

EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1906.

With a view to gaining some knowledge as to their comparative cold resistance and also to determine the factors affecting cold resistance in various strains under moderately light rainfall, a series of

22 strains of alfalfa (see Table I) was sown in duplicate on plats one-fortieth of an acre each in the spring of 1906. One complete set was sown on the best soil on the experiment farm, a rich sandy loam, while the duplicate series was placed on a light sandy piece of land on another part of the farm. The series on sandy soil was sown May 9, 1906; that on the loam May 10.

The following table shows the serial number, the region of origin, and the estimated percentage of stand on both the sand and the loam during the first or seeding year and the percentage of stand remaining after the severe winter of 1906-7.

TABLE I.—*Results of experiments with different strains of alfalfa grown on sandy soil and on loam at Dickinson, N. Dak., during 1906 and 1907, showing the percentage of a perfect stand which survived the winters.*

No.	Origin.	Sandy soil.				Loam.			
		1906.		1907.		1906.		1907.	
		Stand.	Date.	Stand.	Date.	Stand.	Date.	Stand.	Date.
		Per ct.		*Per ct.*		*Per ct.*		*Per ct.*	
[a]D. E. S. 223	Fargo, N. Dak. (Grimm, crop of 1904).	80	Aug. 15	80	June 3	95	Aug. 1	35	June 1
D. E. S. 241	Gladstone, N Dak. (crop of 1905).[b]	......	....	......	....	95	...do....	65	Do.
D. E. S. 282	Commercial alfalfa.[b]	70	Aug. 15	10	June 3	....	....	....	....
[a]S. P. I. 9303	Peru.............	10	...do....	1	...do....	40	Aug. 1	5	June 1
S. P. I. 12604	Provence, France	75	...do....	4	...do....	85	..do....	40	Do.
S. P. I. 11211	Commercial Turkestan.	80	...do....	75	...do....	85	...do....	85	Do.
S. P. I. 12398	Colorado.........	80	...do....	15	...do....	90	...do....	60	Do
S. P. I. 17449	Commercial American.	75	...do....	12	...do....	93	...do....	50	Do.
S. P. I. 12747	Yellowstone Valley, Mont.	75	...do....	20	...do....	90	...do....	65	Do.
S. P. I. 13291	Fayetteville, N. Y.	75	...do....	50	...do....	90	...do....	65	Do.
S. P. I. 12784	Utah (irrigated).	70	...do....	5	...do....	90	...do....	50	Do.
S. P. I. 12816	Milk River Valley, Mont.	75	...do....	15	...do....	80	...do....	55	Do.
S. P. I. 12801	Texas Panhandle.	75	...do....	5	...do....	80	...do....	40	Do.
S. P. I. 13259	Southern Nebraska.	60	...do....	25	...do....	80	...do....	65	Do.
S. P. I. 13237	Chinook, Mont..	75	...do....	4	...do....	85	...do....	55	Do.
S. P. I. 12671	Kansas..........	75	...do....	40	...do....	85	...do....	60	Do.
S. P. I. 12820	Northern Nebraska.	70	...do....	45	...do....	90	...do....	65	Do.
S. P. I. 12748	Rhine Province, Germany.	75	...do....	45	...do....	85	...do....	35	Do.
S. P. I. 14786	Tashkend, Turkestan.	85	...do....	85	...do....	85	...do....	85	Do.
S. P. I. 12409	Utah (not irrigated).	75	...do....	20	...do....	85	...do....	20	Do.
S. P. I. 13858	Kharkof, Russia.	90	...do....	25	...do....	95	...do....	80	Do.
S. P. I. 13857	Simbirsk, Russia	60	...do....	55	...do....	70	...do....	60	Do.
	Average...	72.7	....	29	....	84.6	....	56.1	....

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[a] These abbreviations refer to the serial numbers of the Dickinson subexperiment station and of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry.

[b] These strains were not in duplicate.

It will be noted that the stand on the loam is in nearly every case better than that on the sand and that the loss in stand observed in

907 as compared with 1906 is practically always greater on the sandy oil than on the loam. Although this loss in stand is undoubtedly ue in large part to winterkilling, it is no doubt true that a part of it ay be accounted for by the fact that the sandy soil is much less etentive of moisture than the loam, so that the deterioration of the tand on the sandy soil would be due to a combination of drought nd cold. The likelihood of this will be more apparent after reading he discussion of the precipitation of the autumn of 1906 given below.

RAINFALL.

The rainfall during 1906 was 19.99 inches, while the yearly average ased on a 16-year record is 15.11 inches. Despite the fact that the recipitation exceeded the average considerably, there were times during 1906 and 1907, as may be judged from the following table (Table II), when a lack of moisture interfered notably with the growth of the crop. This was particularly true during July, 1906. The dry spell that occurred in this month was in part responsible for the small growth made on all plats during the season of 1906. The most important factor in contributing to the lack of vigorous growth was the failure to secure inoculation. The effect of inoculation on cold resistance will be more fully discussed later.

TABLE II.—*Rainfall in inches at Dickinson, N. Dak., for 1906, 1907, and 1908.*[a]

	Average for 16 years.	1906.	1907.	1908.
January	0.39	0.25	0.80	0.28
February	.48	.32	.14	.73
March	.99	.98	.39	1.42
April	1.18	1.10	.30	1.27
May	2.43	7.11	1.36	3.50
June	2.92	5.40	2.52	4.30
July	2.12	.16	4.82	1.41
August	1.82	2.64	1.89	1.43
September	1.04	.25	1.11	1.67
October	.70	.14	.10	2.47
November	.56	.87	.02	.78
December	.48	.77	.22	.24
Annual	15.11	19.99	13.67	19.50

[a] This table is quoted from Waldron, L. R., First Annual Report of the Dickinson Sub-Experiment Station for the year 1908, Fargo, N. Dak., 1909.

TEMPERATURE.

The winter of 1906–7 was one of extraordinary severity. The minimum temperature for October was 11° F.; November, −1° F.; December, −24° F.; January, −35° F.; February, −31° F.; March, −8° F.; and April, 5° F. During January there were only two days when the minimum temperature registered was above zero (3° F. on January 1 and 5° F. on January 11) and only one day when the maximum rose above freezing (35° F. on January 23).

In order to show more adequately the nature of the weather wh the experimental alfalfas shown in Table I were called upon to end the report of the Weather Bureau for the month of January, 19 is presented in its entirety in Table III.

Table III.—*Daily record of temperature and precipitation for the month of Jan 1907, at Dickinson, N. Dak.; latitude, 46° 50′ N.; longitude, 102° 50′ W.; alti 2,453 feet.*

Date.	Temperature.				Precipitation.	
	Maximum.	Minimum.	Range.	Record at 6 p. m.	Snowfall.	Depth of snow on ground at time of observation.
	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*
1	5	3	2	4	1	7.5
2	−1	−8	7	−8	1	8.5
3	−1	−20	19	−3		
4	6	−4	10	2		
5	−2	−5	3	−3		
6	5	−4	9	3		
7	6	−7	13	−3	[a] T.	
8	−8	−14	6	−14		
9	14	−23	35	−12		
10	9	−22	13	15		
11	15	5	10	5	3	11.5
12	5	−13	18	−11	[a] T.	
13	−6	−14	8	−9	1	12.5
14	−23	−33	10	−29		
15	−13	−35	22	−13		
16	−9	−16	7	−14	1	13.5
17	11	−22	33	−6		
18	23	−16	39	14		
19	24	−14	38	−14		
20	0	−28	28	0		
21	24	−3	27	−3		
22	12	−13	25	11		
23	35	−3	38	24		
24	30	−6	36	−2		
25	−1	−15	14	−1	[a]	
26	4	−13	17	−5		
27	−4	−20	16	−20		
28	−7	−21	14	−12	1	14.5
29	−6	−25	19	−12		
30	7	−17	24	3		
31	30	−2	32	22		
Sum	184	−428				
Mean	5.9	−13.8				

MONTHLY SUMMARY.

Temperature.

Mean maximum, 5.93° F.

Mean minimum, −13.74° F.

Mean, −3.9° F.

Maximum, 35° F.; date, 23d.

Minimum, −35° F.; date, 15th.

Greatest daily range, 38° F.

Snow.

Total fall, 8 inches.

REMARKS.

Temperature, 15.1° F. below normal.

[a] T.=trace.

An examination of the columns of Table I showing the stand for 1907 reveals the fact that some plants on every plat in both series survived the winter. In several cases the strains came through with no injury whatever, and even the plats of the Peruvian variety, which next to the Arabian is perhaps the least hardy alfalfa known, had a sprinkling of living plants amounting on the sandy soil to about 1 per cent of a stand and on the loam to about 5 per cent.

REASONS WHY ALFALFAS SURVIVED THE WINTER OF 1906–7.

It is surprising, in view of the severity of the winter of 1906–7, which was almost unprecedented in North Dakota, that so large a percentage of alfalfa plants survived. From a careful study of the weather records for Dickinson from September, 1906, to May, 1907, inclusive, it seems that two factors were largely concerned in the result, namely, autumn weather of a kind that induced comparative dormancy before the real winter weather came, and a heavy blanket of snow throughout the coldest winter months.

Beginning with September 10 there was on the whole a gradual downward movement of the mean daily temperature, which culminated in killing frosts on the 26th and again on the 29th of the month. This and the dryness of the soil, the precipitation for the whole month being only 0.25 of an inch, served to harden the tissues of the plant and inhibit the production of new and tender growth.

In October a very similar condition of affairs obtained. A precipitation of only 0.14 of an inch for the whole month was recorded. The temperature went down rather gradually, with killing frosts on the 5th, 9th, and 10th, while from the 18th to the 31st of October the daily minimum temperature ranged from 37° to 11° F., only two days (37° F. on the 25th and 35° F. on the 26th) having minima above the freezing point.

The result of this combination of dryness and gradually increasing cold was first to bring about a gradual cessation of the physiological processes involved in growth, and finally to bring the plants unharmed into a comparatively dormant condition.

Several years of observation have led to the conclusion that a capacity to react with reasonable promptness to stimuli producing dormancy is one of the most important qualities, if not the most important, in producing hardiness in alfalfas and clovers. Similarly during dormancy, resistance to growth-producing stimuli is important.

Elsewhere[a] an attempt has been made to explain the failure of one variety to become dormant while another becomes so, by conceiving varieties and even individuals as having a more or less constant minimum temperature, below which growth ceases in the autumn and above which it starts in the spring. Breeders desiring to establish races for particular purposes should seek wherever possible to correlate one physiological character with another rather than morphological characters with physiological, unless there is a fairly obvious relation between the physical character used as a basis of judgment and the physiological character toward which selection is being made. That dormancy is of paramount importance in determining whether alfalfas will winterkill or not appears to be shown by the results of 1906 and 1907 as compared with those of 1908 and 1909, given later.

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[a] Brand, Charles J. Peruvian Alfalfa: A New Long-Season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 8–14.

No two conditions are more potent than drought and cold in retarding plant growth or bringing it to a complete standstill by hardening the tissues.

Both temperature and moisture conditions were ideal in western North Dakota during the autumn of 1906 for bringing about this result. Those for September and October have already been described.

November weather was generally favorable for inducing dormancy, and a snow covering was present during a portion of the month. The total precipitation for the month amounted to 0.87 inch, of which 0.22 inch fell before the middle of the month and had a good chance to become absorbed by the soil. Only a portion of this soaked in. The remainder of the precipitation was in the form of snow, which remained until the end of the month.

The precipitation for December was above the normal, but nearly all of this came in the form of snow, which remained in place. A short period of warm weather at the beginning of the month removed the snow, but on the 9th and 13th more snow fell, forming a covering over 7 inches deep. The temperature for December was 4.1° F. below the normal. The minimum temperatures ranged from 28° to −24° F., while the maxima ranged from 47° to −1° F. The snow afforded the plants a high degree of protection.

The weather conditions during January, 1907, are shown in Table III and discussed in that connection. Attention here is directed only to the snowfall. The month opened with 7.5 inches (see Table III) on the ground; on the 15th there were 12.5 inches, and at the end of the month there were 14.5 inches. Without this blanket of snow and with the persistently low temperatures that occurred throughout the month it is probable that there would have been 100 per cent of winterkilling on the majority of the experimental plats, and this despite the extremely favorable conditions under which the alfalfa entered the winter. As it was, red clover, winter wheat, and some alfalfa on every one of the twenty-two plats survived the winter.

As is always the case in this northern region, the weather during February, 1907, was also severe, the mean of the minimum temperature being 4° F. and the absolute minimum −31° F. The month began with 14.5 inches of snow on the ground, 6 inches remaining on the 15th and 4 inches at the end.

In order to make possible a comparison of mean temperatures endured by the alfalfas under experiment during the winter of 1906–7 ith those endured by the strains under experiment during 1908–9, he mean temperatures for these years are shown in the following ble:

ABLE IV.—*Mean temperatures for Dickinson,*[a] *N. Dak., during 1906, 1907, 1908, and 1909, the years covered by the alfalfa experiments reported upon in this bulletin.*

Month.	Average for 16 years. (b)	1906.			1907.			1908.			1909.		
		Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
nuary	11.0	28.4	5.8	16.5	5.9	−13.7	−3.9	35.5	6.9	22.1	18.5	−2.6	7.85
bruary	11.9	29.5	5.2	17.2	27.3	4.0	15.6	24.7	6.9	15.7	27.2	6.2	16.70
arch	23.5	31.9	8.1	19.8	41.6	15.6	28.5	34.1	13.6	23.8	37.1	18.2	27.70
pril	42.6	63.0	33.0	48.3	47.5	21.0	34.2	53.7	30.0	44.3	48.6	22.2	44.30
ay	52.6	61.6	38.8	50.3	59.5	29.5	44.5	62.0	37.0	49.5	65.8	38.0	49.50
ne	60.9	73.2	49.2	61.2	72.7	47.8	60.2	71.4	48.6	60.0	74.1	51.2	62.60
ly	68.0	82.9	50.9	66.9	77.6	53.1	65.3	84.9	55.0	69.9	78.3	55.5	66.90
gust	67.2	79.1	53.6	66.3	81.2	49.4	65.3	80.0	48.5	64.2	82.7	54.6	68.60
ptember	56.8	77.8	44.6	61.2	67.2	38.5	52.8	76.4	47.0	61.7	74.7	44.6	59.60
tober	44.0	61.8	31.0	46.4	62.6	31.1	46.3	53.5	31.3	42.4	58.1	30.9	44.50
ovember	27.3	37.2	15.4	26.3	46.4	17.2	31.8	44.6	20.4	32.5	44.8	18.0	31.40
ecember	18.6	25.4	3.6	14.5	36.9	10.2	23.5	27.7	6.6	17.1	17.4	0.0	8.70
Annual	40.3	54.3	28.0	41.9	52.2	24.5	38.8	54.0	29.5	41.5	52.8	28.0	40.70

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[a] The weather records for Dickinson have been kept at the experiment farm since March, 1906, and thus data given are almost identical with those obtaining at the plats, as the two points are less than a quarter a mile apart.

[b] These figures are based on records beginning in 1893, when the first observations were taken.

The most striking thing to be noted in view of the fact that a considerable percentage of the alfalfa plants lived through the winter, espite their lack of vigor due to imperfect inoculation and drought, that the mean for January, 1906 (—3.9° F.), was 14.8 degrees colder han the normal temperature that had prevailed up to that time for hat month, based on a 13-year record.

March, 1907, was slightly warmer than usual, but the snow covering remained until practically the 15th of the month. Though a ight growth began to show in many plants in April, decidedly hibitive minimum temperatures continued throughout the month. here were killing frosts May 1–10, 13–15, 18–19, 26–27; and a final ne on June 5.

The weather was such that the spring awakening was almost as radual as the enforced dormancy of autumn. It was on account f this unusual combination of autumn drought, the gradual coming of winter, the protective covering of snow, and the gradual return f spring that some of even the tenderest alfalfa varieties came hrough this winter, which was one of almost unparalleled severity.

TERMINATION OF EXPERIMENTS BEGUN IN 1906.

Although a moderately good stand of alfalfa was obtained, th average for all plats on the sandy soil being 72.7 per cent and fo those on the loam 84.6 per cent, the condition of the 1906 seeding was never satisfactory. The following statement upon this expe ment is found in the records for 1906: "The alfalfa on these pla is a failure, due almost entirely to acute nitrogen starvation. Th plants were not inoculated * * * and they were of weak, sickl appearance."

This lack of inoculation primarily, together with the dry autum of 1906 and the severe winter that succeeded it, kept the plants i an unthrifty condition. Following this, the summer of 1907 was o of the driest of recent years. A total of only 13.67 inches of rain fe while in 1906 and 1908 there were 19.09 inches and 19.50 inche respectively.

This combination of trying conditions kept the plats in such a unpromising state that in the late autumn of 1907 they were plowe up to make room for other crops.

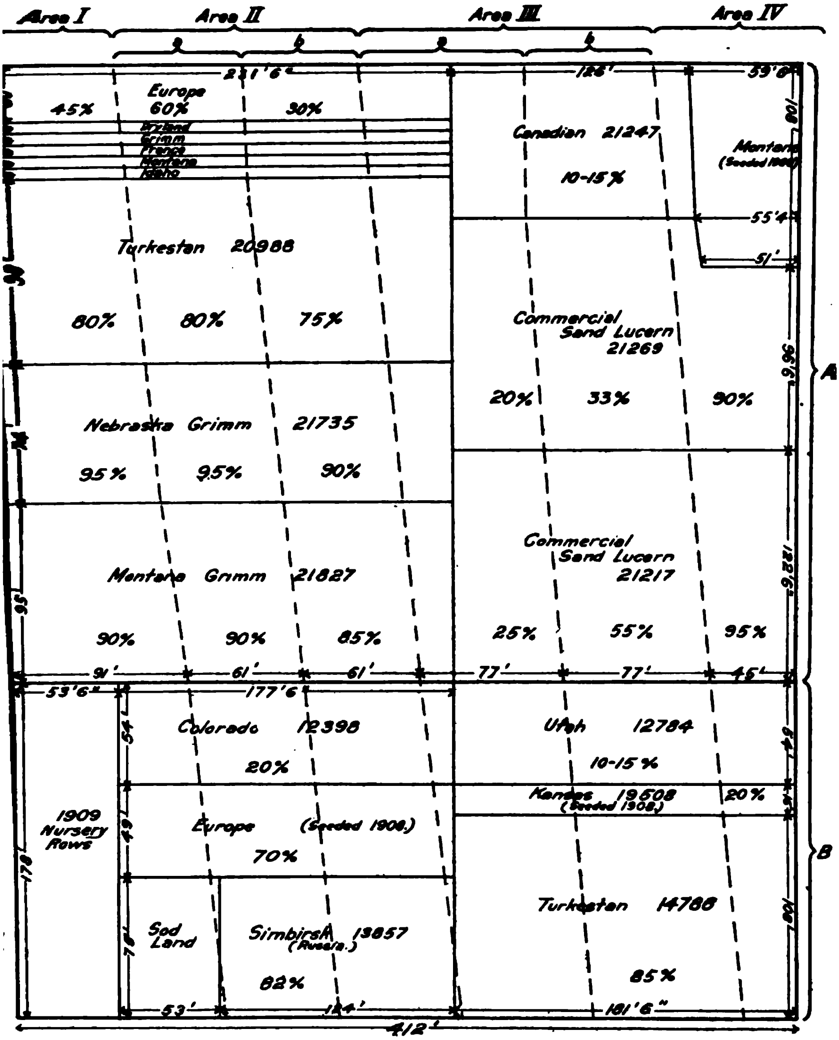
FIELD PLAT EXPERIMENTS AT DICKINSON, N. DAK., BEGUN I 1907.

In the spring of 1907 a second experiment was started. Only fo regional strains were seeded. Two samples of American alfalfa, o from Colorado and one from Utah, and two strains that had show some degree of hardiness in the 1906 experiments, one from Turkesta and one from Simbirsk, Russia, were selected. At this time no see of the Grimm alfalfa of Minnesota was available for use.

DIVERSITY IN PREVIOUS TREATMENT OF LAND USED.

The different portions of the field on which the experimental pla were located had not had the same cultural history. The virgin so was broken in different years in some cases; some parts in autum others in spring; one part was left without a crop the first year, i other years the different parts bore different crops; one part receive a dressing of rotted manure in a year when none of the others we fertilized.

These diversities of cultural history furnished an unusually goo opportunity to study their effect on cold resistance. As interestin differences occurred in the amount of winter loss on different are of the field, Table V and text figure 1 are inserted to show the differen treatments these areas had received. As the 1908 field plats to b ussed later were seeded on an adjacent part of the same field, y also are shown in the figure.[a] Table V presents the history of



G 1.—Ground plan of the experimental field plats of alfalfa in 1907 (*B*) and 1908 (*A*), showing their location and estimated percentage of stand in June and August, 1909, and, in connection with Table V, the previous cropping and treatment of the various areas composing the field. (Scale, 1 inch = 100 feet.)

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[a] The 1908 field plats are fully discussed on pages 23 to 30, inclusive, but the riter's desire to call especial attention to the fact that the great differences in stand served in 1909 on the various portions of these plats are due in large part to tillage fects and to differences in previous cropping and not to winterkilling.

The extent to which winterkilling was effective in thick as compared with thin ands may be seen best by a study of Table VIII, page 23. A comparison of the wo "Total" and two "Loss" columns in this table shows that the percentage of ss was greater in every case on the square yard having the thinner stand; that is, he smaller total number of plants.

each area of the plats shown in figure 1. Estimations of the stand were made early in June, 1909, and again late in August.

TABLE V.—*Record of previous crops grown and of treatment given the land used for the experimental field plats of alfalfa in 1907 and 1908.* [*See also fig. 1.*]

Year.	Area I.	Area II.	Area III.	Area IV.
1904	Virgin prairie.........	Virgin prairie.........	Prairie—had been broken some years before, cropped, and then allowed to return to sod.	Virgin prairie.
1905	Broken in spring, not seeded, and grew up to Russian thistles.	Virgin prairie.........	Rebroken in spring and sown to oats. Fall-plowed.	Virgin prairie.
1906	Small-grain plats. Plowed and disked in autumn.	Broken up in October.	Grain. Fall-plowed .. *B*, Manured on stubble in autumn.	Broken up in October.
1907	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.
1908	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).
1909	*A* and *B*, Alfalfa.......	*A* and *B*, Alfalfa......	*A* and *B*, Alfalfa......	*A* and *B*, Alfalfa.

SOIL PREPARATION, WEATHER CONDITIONS, AND OTHER OBSERVATIONS DURING 1907 AND 1908.

In the spring the land for the 1907 plats was double-disked and harrowed on April 25 and double-disked crosswise and harrowed on June 1. Seeding took place on June 5, after a good rain. The rainfall of the summer was fairly adequate, though almost half of the 4.82 inches shown in Table II for July, 1907, occurred in two heavy storms only three days apart. Over half of the August rain fell in one storm. The autumn was dry. September had about a normal precipitation, while October had only 0.10 inch and November only 0.02 inch.

The first killing frost did not occur until September 29. Before this time growth had stopped and the plants had become practically dormant because of the dry weather. Russian thistles, more drought resistant than alfalfa, came up thickly and overtopped the latter. An ideal plant covering to hold snow was created. On October 11, 1907, the condition of the plats was noted. The estimated percentage of stand on this date for each plat was as follows:

	Per cent.
Turkestan (S. P. I. No. 14786)................................	80
Simbirsk, Russia (S. P. I. No. 13857)................................	70
Utah, irrigated (S. P. I. No. 12784)................................	90
Colorado, irrigated (S. P. I. No. 12398)................................	90

The winter of 1907–8 was an unusually mild one; the average temperature for the winter months was 20.4° F., this being almost 7 degrees above the 16-year normal.

The lowest temperature of the winter occurred on February 1 and as preceded by two days of snow. This was the only really cold ell experienced during that season, and the alfalfa was amply pro- cted by snow throughout the period.

Mild as this winter was, some winterkilling occurred in all the rains. The amount was negligible in the Turkestan and Russian rains, the former showing the smaller loss. The Colorado and Utah lats suffered some loss, though not enough to reduce them to unprof- ableness. All stands were sufficient to justify leaving the plats over uring the winter of 1908–9. They will receive further discussion in onnection with the field plats seeded in the spring of 1908.

A fact of some interest was noted regarding the comparative hardi- ess of alfalfa and red clover during this dry open winter. Six lats of the latter on land adjacent to the Simbirsk and Turkestan lats showed losses in stand ranging from 55 to 95 per cent.

In order to show the temperature conditions endured by the 1907 eeding as compared with the 1906 and 1908 experiments, Table VI s presented.

ABLE VI.—*Monthly mean temperatures for the winters of 1906, 1907, and 1908, at Dickinson, N. Dak.*

Month.	Monthly mean.			
	Average for 16 years.	1906–7.	1907–8.	1908–9.
	°*F.*	°*F.*	°*F.*	°*F.*
November	27.3	26.3	31.8	32.5
December	18.6	14.5	23.5	17.1
January	11.0	−3.9	22.1	7.9
February	11.9	15.6	15.7	16.7
March	23.5	28.5	23.8	27.7
Mean	18.5	16.2	23.4	20.4

The Turkestan and Russian strains of alfalfa not only did not suffer serious loss, but by the summer of 1909 showed an improved condition of stand. This change was one of appearance and not an actual thickening of the stand. It varied in the different areas shown in figure 1 and appeared to be due in large part to a progressive inoculation of the soil with nitrifying bacteria as the plants became better established.

The most important fact gleaned from the small experiment begun in the spring of 1907 was that the common form of alfalfa, which in a little more than half a century has been extended so generally over the western half of the United States and which has for many years proved sufficiently hardy throughout Kansas and over a large part of Nebraska, is not cold resistant enough to endure perfectly even mild winter in the coldest parts of the Great Plains.

The autumn of 1907 furnished another illustration of the importance of dry weather during the fall in producing dormancy. The winter as a whole, was an open one, but there was a snow covering of utility during the only critical period. Although the winter was an abnormally mild one, these two factors were probably dominant in the comparatively successful wintering over of the two American strains. These same factors and a greater inherent hardiness appear to have produced the better results observed in the Turkestan and Simbirsk varieties.

WINTERKILLING (1908–9) AND YIELDS (1909) OF THE 1907 FIELD PLATS.

The winter of 1908–9 is discussed fully later in connection with the 1908 row experiments; hence it need not be taken up in this connection. Its effect on the 1907 field plats, as determined in the spring of 1909, is shown in Table VII. The figures presented in this table were secured in May, 1909, by counting the living plants and the winterkilled crowns on selected square yards which showed the highest and lowest amount of loss.

TABLE VII.—*Results of experiments showing the relative proportion of winterkilling (1908–9) of the alfalfas in the experimental field plats of 1907 and their yield in 1909.*

S.P.I. No.	Strain.	Plants on square yard showing the least winterkilling.				Plants on square yard showing the greatest winterkilling.				Yield of whole plat.
		Living plants.	Dead plants.	Total.	Loss.	Living plants.	Dead plants.	Total.	Loss.	
		Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Number.*	*Number.*	*Per cent.*	*Pounds.*
13857	Simbirsk, Russia....	69	23	92	25.00	45	33	78	42.30	2,06[illegible]
12398	Colorado....	236	70	306	22.87	32	191	223	86.09	1,13[illegible]
14786	Turkestan...	120	10	130	7.69	31	30	61	49.18	2,5[illegible]
12784	Emery, Utah.	20	91	111	81.98	4	127	131	96.94	1,175

A comparison of the figures in the percentage of loss columns in Table VII will show how great the differences in winter loss were in the same varieties, but on different parts of the same plat. Some discussion of the particular factors that may have produced these differences will be taken up in connection with the 1908 field plats.

Attention here is directed only to Colorado alfalfa, S. P. I. No. 12398, which originally had an unusually thick stand over the whole plat. On the square yard where the least winterkilling had taken place only 70 plants (23 per cent) out of 306 were killed, while on the other 191 (86 per cent) out of 223 succumbed.

ELD PLAT EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1908.

WINTERKILLING AND YIELDS.

In the spring of 1908 a second series of field plats was seeded by the bexperiment station at Dickinson, N. Dak. These are in charge of e junior writer cooperating with Mr. J. M. Westgate, Agronomist in e Office of Forage-Crop Investigations. As may be seen by reference to figure 1, the new seedings are situated immediately north of e 1907 field plats and share with these the diversities in the previous ropping and treatment shown in Table V.

Counts of all the living and dead plants on selected square yards ere made, as in the case of the 1907 seedings. The results are hown in Table VIII.

ABLE VIII.—*Results of experiments showing the relative proportion of winterkilling (1908–9) of the alfalfas in the experimental field plats of 1908 and their yield in 1909.*[a]

P.I. No.	Variety or strain.	Plants on square yard showing the least winterkilling.				Plants on square yard showing the greatest winterkilling.				Calculated yield per acre.
		Living plants.	Dead plants.	Total.	Loss.	Living plants.	Dead plants.	Total.	Loss.	
		Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Number.*	*Number.*	*Per cent.*	*Pounds.*
0968	Turkestan	99	8	107	7.47	60	30	90	33.33	1,156
1735	Grimm (Nebraska)	87	1	88	1.13	42	5	47	10.63	1,474
1827	Grimm (Montana)	76	0	76	0.00	51	0	51	0.00	1,487
	Europe[b]	88	0	88	0.00	40	9	49	18.35	2,136
1247	Canada	78	9	87	10.34	8	6	14	42.85	912
1269	Darmstadt, Germany	100	41	141	29.07	22	11	33	33.33	1,603
1217	.....do	45	0	45	0.00	18	13	31	41.93	1,960
9508	Kansas[c]	65	36	101	35.65	16	23	39	59.00	1,044

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[a] Mr. Charles H. Clark, Special Agent, Crop Physiology and Breeding Investigations, Bureau of Plant Industry, rendered painstaking and efficient help in making many of the determinations presented in this paper. Mr. O. J. Grace, Acting Superintendent, also rendered much assistance.

[b] This plat is located between two plats sown in 1907. The seed was imported as sand lucern from Europe for the substation. On an examination of the plants it proves to be neither the true sand lucern nor the so-called commercial or false sand lucern. It is almost wholly lacking in variegated flower color, and by its general habit of growth, appearance, leafage, etc., suggests the possibility that it is a Turkestan alfalfa adulterated with a small quantity of ordinary middle European alfalfa. The plat shown in the upper left-hand corner of figure 1 is from the same seed. Its yield was not taken.

[c] This plat is also located between two 1907 plats (see figure 1). According to Mr. J. M. Westgate it was grown from seed a part of which at least was from a field planted with variegated-flowered alfalfa seed, presumably procured originally from central Europe.

OBSERVATIONS ON DIVERSITY OF CONDITIONS.

Several interesting conditions were observed on both the 1907 and 1908 plats. These are shown in a measure in Tables VII and VIII and in figure 1. The following deserve especial consideration:

(1) Differences in the original stand on different parts of the same plat. This becomes evident on comparing the columns marked "Total" for each plat shown in Table VIII.

(2) Differences in the amount of winterkilling on different parts of the same plat. In these cases the greater percentage of loss appears to have taken place on the part that had the poorer stand originally.

(3) Differences in the percentage of loss in the two Grimm samples, despite the fact that these were both grown from the same original stock.

(4) Differences in the color and vigor of the plants and finally in the amount of growth on the different areas. The latter finds partial expression in the diversities in yield.

(5) Differences in yield which show practically no correlation to any of the conditions mentioned above except the last.

Differences in Original Stand.

That some of the differences in the original stand are due to differences in the preparation of the soil and the previous cropping is probable, as they follow exactly the division lines of the "lands," shown by the broken lines in figure 1, page 19. How sensitively alfalfa reacts to even slight variations in preparing the soil is shown on both Areas II and III, but especially on the latter. Here the uphill or east furrows have a much better stand and higher growth than the downhill or west furrows.

To show more concretely the diversities in stand on the differently treated strips of the field after the winter of 1908–9, the estimated percentage on each for all plats is stated in figure 1. In the case of plat 21217 the difference in estimated stand between the east and west ends amounts to fully 70 per cent.

The soil was very dry in the fall of 1906 when the sod was broken up on Area II, so dry, in fact, that the plowman had great difficulty in getting his plow to "bite" when going down hill.

Differences in Amount of Winterkilling.

The differences in the amount of winterkilling are traced with greater difficulty and less certainty than those producing differences in the original stand. However, there are certain interrelations. The square yard of each plat showing the thinner stand suffered the greater loss in each case. Hence, a lack of thickness of stand itself probably has an important bearing. An inferior snow-holding capacity results and a greater consequent exposure to the weather. Furthermore, thick stands, through greater transpiration, more quickly exhaust excess moisture from the soil. The probable importance of this factor is more fully discussed later.

Another factor both directly and indirectly of importance in winterkilling on the 1907 and 1908 field plats is inoculation. Its direct importance rests on the robustness, vigor, and generally greater hardihood that results from perfect nutrition. Inoculation conduces to a better root development, higher growth, and more leafage, the two latter making a more nearly perfect covering to bind the winter's snow.

DIFFERENCES IN COLD RESISTANCE OF TWO SAMPLES OF GRIMM ALFALFA.

The difference in the amount of winterkilling in the two Grimm amples raises the important and interesting question as to what ause or causes this is due.

Both the Montana and Nebraska seed were grown from S. P. I. o. 12991, the former at Chinook, in northern Montana, and the later at Alma, in southern Nebraska, near the Kansas line. Grimm o. 12991 was grown in Minnesota in 1904. The weakness of the ebraska race as compared with that from the Montana seed was nly slightly apparent where the stand was thickest, but amounted o over 10 per cent on the square yard with the thinner stand.[a]

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[a] The difference in the winter hardiness of the two Grimm samples is not so great s to be outside the limit of possible error in field plat work. This is especially true f the present plats, which were put in only with ordinary care on land showing a ide range of diversity in tillage effects. Nevertheless, several possibilities that uggest themselves as being concerned in this difference in cold resistance deserve otice in this connection:

(1) Free hybridization between the Grimm field and neighboring fields of the far ess hardy ordinary alfalfa. Common alfalfa is grown in both sections; hence there ould be some tendency toward equalization as to the factor. However, natural election toward cold resistance is operative every winter in northern Montana and ery rarely operative in southern Nebraska. The result of this should be a hardier ace of common alfalfa in Montana than exists in Kansas or in Nebraska south of the Platte River. There is little doubt that this is actually the case, both from experimental evidence and from the fact that there is a general demand for Montana seed n preference to Kansas, Nebraska, or Utah seed for use in cold regions. Hence, the eakness that probably results from hybridization would be greater in a measure in the southern-grown race.

(2) Further selection toward cold resistance in Montana and a slight reversion, if anything, in southern Nebraska. Alma is approximately 300 miles farther south than the Grimm section of Minnesota and 600 miles south and almost as much east from Chinook.

The selective power of the Montana as compared with the Nebraska climate is shown in a measure by the monthly minima for Alma and Chinook presented in the following table. The winters shown are those that intervened between the seeding, which took place in the spring of 1905, and the harvesting in the fall of 1907 of the seed used at Dickinson on the 1908 field plats.

Minimum monthly temperatures for the cold months of 1905, 1906, and 1907 at Chinook, Mont., and Alma, Nebr.

Locality.	Winter of 1905-6.						Winter of 1906-7.					
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Chinook[a]	−8	−28	−18	−21	−16	−25	15	−7	−15	−45	−43	−8
Alma	17	5	6	−3	−2	−14	16	7	2	0	−6	

[a] The records for both Chinook and Havre, Mont., were used in securing these minima on account of gaps in the record of the former.

Another point to be noted in Table VIII with reference to the Grimm samples is that the one whose loss from winterkilling was greater, nevertheless gave practically the same yield as the one that suffered no loss. This is due to the fact that the Nebraska Grimm alfalfa had fully 5 per cent better stand on the plat as a whole than the Montana Grimm.

The following comparison of their germination gives a reasonable explanation of this difference in stand, and at the same time brings to light another difference in the progeny of S. P. I. No. 12991 as grown in Montana and Nebraska quite as profound as the diversity in hardiness, namely, in the percentage of hard seed.

S.P.I. No.	Strain.	Germination.	Hard seed.
		Per cent.	*Per cent.*
21735	Grimm (Nebraska)	77.5	16.00
21827	Grimm (Montana)	45.5	42.75
12991	Grimm (Minnesota)	60.0	36.50

The percentages of germination and hard seed of the Nebraska-grown stock are the average of five tests, those of the Montana of two tests. These tests were made in the winter of 1908. In the spring of 1909 both strains were again tested, with the following results:

S.P.I. No.	Strain.	Germination.	Hard seed.	Length of test.
		Per cent.	*Per cent.*	*Days.*
21735	Grimm (Nebraska)	83.5	10.0	4
21827	Grimm (Montana)	53.5	30.5	5

The subject of hard seed is little understood, and attention here is directed to it only because it accompanies an observable difference in hardiness in the same race grown under unlike climatic conditions.

The difference in winter weather shown by these minima is a great one, and might of itself be a sufficient explanation of the difference in the winter loss of the two Grimm plats.

(3) The third factor of probable influence is new-place effect, due to a disturbance of local adjustment in the variety brought about by transporting it from one set of conditions to another. The warm climate at Alma would be especially likely to call forth new-place diversities. It is of course impossible to determine the amount of change any one of the factors discussed may have produced. Their potency, however, is scarcely open to question.

The important phenomenon of local adjustment in cotton varieties has been discussed recently by Mr. O. F. Cook in "Local Adjustment of Cotton Varieties," Bulletin 159, Bureau of Plant Industry, September, 1909. Observations made the past season by the senior writer of the present paper indicate that this phenomenon also occurs in alfalfa when subjected to a change of place.

DIFFERENCES IN COLOR, VIGOR, AND AMOUNT OF GROWTH OF PLANTS.

The differences in the color, vigor, and amount of growth of alfalfa lants find partial expression in Table VIII in the figures giving ields, which are discussed below. They are so evident on the plats hemselves as to suggest immediate inquiry.

On September 1, 1909, the plants of the 1908 seedings on Area IV fig. 1, p. 19) averaged fully 16 inches high, those on Area III about 8 nches, while those on Areas I and II averaged about 7 and 8 inches, espectively. Furthermore, the plants of the thick stand on Area IV had the healthy dark-green color of well-inoculated alfalfa, while Areas I and II had unthrifty plants of a pale yellowish green. On Area III even the plants making up the thin stand on both up and down furrows showed more growth and better color than did the plants on Area II.

DIFFERENCES IN YIELD.[a]

In view of the differences in the extent of winterkilling and in the carefully estimated percentages of present stand, shown in figure 1, the diversities in yield for the different plats are decidedly interesting. Take, for example, S. P. I. No. 20988, which lost only about 7½ per cent of the plants on a selected square yard where the stand was thickest and 33⅓ per cent where thinnest. Compare this with S. P. I. No. 21269, which lost over 29 per cent on the better part of the plat and 33⅓ per cent where the stand was poor. Although there is no great difference in the average number of living plants remaining on the better portions of both plats, and the number of living plants on the poorer part of No. 20988 is fully three times as great as that on the corresponding part of No. 21269, the latter outyielded the former by 450 pounds per acre.

About September 1, 1909, careful estimates were made and the following comparison shows the stand on the different areas of both plats:

S.P.I. No.	Strain.	Good.	Medium.	Poor.
		Per cent.	*Per cent.*	*Per cent.*
20988	Turkestan	80	80	75
21269	Commercial sand lucern	90	33	20

A similar disagreement in yield and stand exists between S. P. I. Nos. 21217, commercial sand lucern, and 21827, Montana-grown Grimm alfalfa. Although the former has a thin stand over two-thirds of the plat and showed some winterkilling where the stand was thin, while the latter was wholly uninjured and has on the whole a far thicker stand, still No. 21217 gave a yield of 2,000 pounds per acre, while No. 21827 produced only 1,487 pounds.

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[a] See Table VIII, p. 23, in connection with this discussion.

An even more striking result is apparent on comparing Turkestan, S. P. I. No. 20988, in Table VIII, with Utah, S. P. I. No. 12784, in Table VII. The average winterkilling for the two parts of the Turkestan plat was about 20 per cent, with 80 per cent of a perfect stand remaining. The Utah plat winterkilled almost 90 per cent and still, according to the scales, produced as much hay as the Turkestan. A part of this discrepancy may be explained by the general inoculation of the surviving plants of the Utah strain, but the controlling factor was the weeds harvested and weighed with the alfalfa.

Weeds constituted a large proportion of the product of all the plats or parts of plats which had thin stands originally or which suffered severe winter losses. In the 1907 section of the field the latter condition applies particularly to the Utah, Kansas, and Colorado strains, and the former in a measure to all parts of the plats included in Areas II and III. On the western two-thirds of the east tier of the 1908 plats the stand of alfalfa was very light, and weeds made up a large part of the hay yield. The three plats on the west side of the field (see fig. 1, p. 19) had sufficiently thick stands of alfalfa to hold the weeds under complete check. The Canadian plat's product, small as it is, was still more largely made up of weeds. The original seeding on this plat was very thin.

These differences are traceable almost wholly to inoculation. Almost one-third of plat 21217 (all of Area IV) is perfectly inoculated, while only scattering plants on 21827 show signs of inoculation. As previously stated, on September 1 the growth on Area IV averaged about 16 inches high, while that on Areas I and II was less than 8 inches. The yields given are for the first crop. Those for the second crop vary even more strikingly, but are not given, as rains made it necessary to scatter and rebunch the hay several times. In doing this some confusion arose, making the figures as a whole unreliable, hence their omission.

That the diversities in yield commented upon are really due to a difference in the extent of inoculation is readily apparent upon even a casual examination. A comparison between the 1908 plats (Table VIII) and the 1907 plats (Table VII) furnishes additional evidence that is of interest. The latter are uniformly inoculated, while the former are not.

The average stand on Turkestan plat No. 14786, seeded in 1907, is practically identical with that of Turkestan No. 20988, seeded in

08. The yield of the former, 2,502 pounds per acre, was more than ice that of the latter, which gave only 1,156 pounds.

Another factor with reference to the 1908 field plats that deserves ention is a difference in the amount of seed applied to the different ats. The following shows the rate per acre at which the seeding the various strains of alfalfa was done:

	Pounds.
Turkestan (S. P. I. No. 20988)	15.4
Sand lucern (S. P. I. No. 21217)	13.7
Sand lucern (S. P. I. No. 21269)	9.2
Grimm (S. P. I. No. 21827)	13.9
Grimm (S. P. I. No. 21735)	10.2
Canadian (S. P. I. No. 21247)	4.4
Kansas (S. P. I. No. 19508)	14.9

IMPORTANCE OF INOCULATION.

As the foregoing discussion shows, many factors, some of them robably unrecognized, interacting in a complex and imperfectly nderstood manner, must be taken into consideration in comparing he yields given of the different plats, and too great reliance must ot be placed on them.

Another plat of Grimm alfalfa seeded in 1908 with Minnesota seed gives an opportunity for comparing the same variety under uniform field conditions with the Grimm as grown under the very dissimilar onditions prevailing on the 1908 experimental seedings. The small field of Grimm which is referred to as the "valley plat" is located in a slight depression farther up the slope and about 600 feet northwest of the 1908 field plats. It was seeded the same day as the latter and has a perfect stand except at one point where evidently some of the drill hose became clogged. The valley plat contains a net area of 1.22 acres and produced 4,098 pounds of cured hay per acre for the first cutting. This yield should be compared with the Nebraska-grown Grimm which had only a slightly poorer stand, but produced less than 1,500 pounds of hay per acre. The former had general inoculation, while the latter had practically none. It might be mentioned that a pure culture was used to inoculate the seed sown on the Nebraska Grimm plat, while the valley Grimm plat was inoculated both with a pure culture and with alfalfa dirt. In this case the soil inoculation appears to have been the more efficacious, though diversity in conditions makes satisfactory comparisons impossible. The valley plat soil is somewhat better, though the two soils do not differ materially. The valley plat, originally virgin prairie, was broken and disked July 20, 1907. It was well disked and harrowed in the spring of 1908 and seeded to alfalfa May 27, 1908. It is commonly believed that alfalfa does not do well on new ground.

That inoculation has even more direct relations to cold endurance than those already discussed appears to be shown by observations made during the autumn of 1909.

On the night of September 25 a light frost occurred. During the following day Mr. Clark made the interesting observation that the well-inoculated parts of all plats remained uninjured, while the parts that had only slight inoculation or none at all were markedly affected. During the night of October 8 a sharp frost (24° F.) occurred, which affected all areas alike except Area IV. The latter had the heavy growth, dark-green color, and general robustness that accompany perfect inoculation. The same observations were recorded for the valley plat of Grimm alfalfa, which has like evidences of inoculation but is located farther up the slope and northwest from the 1907 and 1908 field plats; however, in this case a slightly higher altitude must also be taken into consideration.

Similar observations as to the frost resistance of inoculated plants were also recorded in the case of well-inoculated row experiments located alongside the field plats.

DRILL-ROW AND HILL EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1908.

In the early spring of 1908 arrangements had been concluded for a more comprehensive test of the hardiness of alfalfa than any previously undertaken in the United States.

In accordance with the plan that was made, sixty-eight strains or numbers were sown on May 15 in duplicate series. One complete set was sown in drill rows 3 feet apart with one row of each kind. These rows are 50 feet long, and as the summer advanced the plants in them were thinned out to one every 8 to 12 inches, leaving only the most vigorous plants. The second series was in hills 2½ feet apart. There were 25 hills of each strain which during the summer were thinned out to one individual in each hill. The hills of each strain were planted at the end of the drill rows, so that both methods of seeding were combined in one continuous row.

The experimental plat, the soil of which is a rich, black, sandy loam, lies near the base of a ridge that extends in a general east and west direction and furnishes some degree of protection from the prevailing winter winds which come from the Northwest. The plat slopes slightly toward the middle on account of a slight depression running diagonally across it. This affects nearly all rows equally.

SOIL OF EXPERIMENTAL AREA, PREVIOUS CROPPING, AND PREPARATION.

The area used for the drill-row and hill experiments was virgin airie which was first broken in the spring of 1905 and planted to es. The land was plowed in the fall of 1905 and then disked. It s disked and harrowed in the spring of 1906 and sown broadcast small clover plats. The land was plowed in the fall of 1907 about nches deep and worked down. The ground was well worked in the ring of 1907 with a disk and harrow before starting the alfalfa periment. The soil was inoculated by sowing earth, taken from experimental alfalfa plat on the station farm, broadcast at the rate about 400 pounds per acre.

The soil would probably be described as a fine black, sandy loam— e Morton loam as described by the Bureau of Soils. The following echanical analysis is furnished by the Bureau of Soils of the United tates Department of Agriculture:

No. of mple.	Description of soil analyzed.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
13634	Top, 8 inches..........	0.4	0.9	1.4	10.6	19.3	47.3	20.1
13635	Second, 8 inches.......	.3	.3	.9	9.7	20.4	42.0	26.5

ORIGIN OF STRAINS USED IN EXPERIMENT.

The strains used in the experiment were chosen with a view to assembling a fairly complete collection of the cultivated alfalfas of the world; but in the case of American-grown seed no attempt was made to represent a climate milder than that of central Utah, previous observations having shown that no degree of hardiness worthy of note could be found in seed from the milder States of the West and Southwest. Irrigated and unirrigated or dry-land strains were included in the plan in order to secure accurate data as to whether the characters producing drought resistance were in any way correlated with those producing cold resistance.

To give a fuller conception of the wide range of climatic and other conditions represented by the sixty-eight strains, Table IX, showing their geographical origin, is presented.

TABLE IX.—*Record of the geographical origin of the sixty-eight strains of alfalfa grow in the drill-row and hill experiments at Dickinson, N. Dak., in 1908–9.*[a]

- North America (26):
  - Canada (2).
    - 42, 43.
  - Mexico (2).
    - 44, 45.
  - United States (22):
    - Colorado (1) irrigated.
      - 47.
    - Kansas (1).
      - 48.
    - Minnesota (1).
      - 51.
    - Montana (3) irrigated.
      - 12, 41, 49.
    - Nebraska (3).
      - 26, 50, 53 (dry land).
    - North Dakota (2).
      - 52, 68.
    - South Dakota (2).
      - 50, 54.
    - Utah (9).
      - Irrigated (4).
        - 1, 5, 10, 64.
      - Not irrigated (5).
        - 19, 22, 55, 56, 65.
- South America (5):
  - Argentina (3).
    - 14, 15, 16.
  - Ecuador (1).
    - 13.
  - Peru (1).
    - 11.
- Europe (15):
  - France (5).
    - 23, 24, 25, 57, 60.
  - Germany (5).
    - 17, 58, 59, 62, 63.
  - Italy (1).
    - 61.
  - Russia (2).
    - 27, 29.
  - Spain (1).
    - 21.
  - Commercial (1).
    - 46.
- Asia (19):
  - Arabia (4).
    - 6, 7, 8, 9.
  - Mongolia (3).
    - 2, 3, 4.
  - Turkestan (12).
    - 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 67.
- Africa (3):
  - Algeria (2).
    - 18, 66.
  - Tunis (1).
    - 20.

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[a] The figures in parentheses indicate the number of strains from the country or State named, while those without parentheses refer to the numbers of the rows in which the strain was grown, as shown in Table XIII.

Numerous strains known to be tender, especially from foreign sources, were included for comparison. The least hardy of these were the Arabian and Algerian strains, and the Andean variety represented by the strains from Peru and Ecuador.

On account of the great interest that has been taken in Turkestan alfalfa, especially in the Northwest, where much has been claimed for it in the way of hardiness, a selection of twelve strains from that country was included in the test.

WEATHER CONDITIONS DURING THE SUMMER OF 1908.

The spring and summer of 1908 were exceedingly favorable for getting a catch of alfalfa. Seeding was completed on May 15 and was followed by prompt germination. A good stand was secured in practically all of the rows, such deficiencies as occurred being due chiefly to poor germination. As may be seen from Table II, the rainfall was ample. Indeed, all the conditions except a frost that occurred

August 22, which did not do permanent injury, were more favor-le than had prevailed in any previous year since experimental work gan at this place. Growing weather continued without interrup-n until the 27th and 28th of September, on which dates killing sts occurred. Thereafter the weather grew gradually cooler. illing frosts came again on October 7, 10, and 11, and beginning th the 17th continued nightly with one exception to the end of the onth. Nearly all growth had ceased in the strains in the nursery r October 23. The minimum temperatures fell gradually during e first half of November, culminating in zero weather on the night the 14th.

By the end of September, when growth-inhibiting frosts began, all the alfalfas had become fully established. They had been clipped ce during the summer (on August 5), and the second growth had ached an average height of 12 inches or more. The crowns had ooled out well and the plants were vigorous and of a healthy color, ving become well inoculated.

In discussing the experiments begun in the spring of 1906, emphasis as laid on the belief that the dryness that prevailed during the fall that year was one of the very important favorable factors that abled a part of all of the 22 alfalfas under test to pass unharmed rough the unprecedentedly severe winter of 1906–7. This has been iscussed in some detail earlier in these pages.

The following statement of the rainfall for September and October 1906 and 1908 shows an important disparity:

	Average for 16 years.	1906.	1908.
	Inches.	*Inches.*	*Inches.*
eptember	1.04	0.25	1.67
ctober	.70	.14	2.47

AUTUMN MOISTURE AND ITS EFFECT ON DORMANCY.

In respect to the factor of autumn moisture and its effect on the lormancy of alfalfa plants, conditions in 1908 were vastly different rom those of 1906. The figures given above show the wide differ-nce in the quantity of rain that fell. In the humid portions of the United States a precipitation of approximately 1½ inches in Septem-ber and 2½ in October occasions no comment, but in the dry parts of the Great Plains it is very unusual. Only one other October (that of 1898) during the 16-year period covered by the Dickinson records had a greater precipitation than that of 1908. The rains of these months fell in such a manner that they were largely taken up by the soil. Furthermore, the amount of moisture available to each plant is far greater in stands sown in rows and hills than thick stands secured by the ordinary methods of seeding. T appearance of the experiment on October 1, 1908, is shown in Plate figure 1 (frontispiece).

As a result of this moist condition, the plants went into the co weather that came toward the end of October (16° F. on the 23d) in comparatively unhardened condition. Temperatures inhibitory growth occurred late in September and at intervals during Octob but these did not occur frequently enough nor were they long enou sustained to produce the gradual and complete dormancy observed 1906.

By the middle of November, zero weather having arrived short before, it was no longer possible to find growing stems either in t drills or hills. On the other hand, in the field plats mentioned Tables VII and VIII, which were sown thickly in the usual way, was possible as late as the 20th of the month to find plants with ste still in a fresh and growing condition.

Inasmuch as the winter as a whole dealt much less severely with t field experiments than with the rows, a careful canvass has be made of all possible explanations. It is rarely, if ever, possible tell positively in such cases as this what particular factors broug about the results observed, but it seems probable that the field pl escaped the injury suffered by the hills and rows for some or all the following causes: (1) The greater protection due to thick sta the thicker stand serving to hold the snow; (2) the warmer location a pronounced slope (the rows are located near the base of this slope (3) the only cutting of the 1907 and 1908 field plats being done mu earlier than the cutting of the rows, the tissues in the plants of t field plats had a chance to become hardened, and finally (4) o account of the dry condition of the soil in the plats as compared wi the rows. The last factor might have acted directly upon the roo of the plants through the temperature and indirectly by bringi about a hardening of the tissues of the plants in the field plats. Th dryness was brought about by the far greater run-off due to hard uncultivated topsoil and sidehill location.

AMOUNT OF SOIL MOISTURE IN ALFALFA STANDS OF VARYIN THICKNESS.

Unfortunately, determinations of the percentage of soil moistur in the field plats, hills, and drill rows were not made in the autumn o 1908. In the spring of 1909, experiments were undertaken t determine the drying effect on the soil of alfalfa stands of varyin thickness. In these experiments Grimm alfalfa plants from a 190 eding were transplanted into plats with definite distances between e plants. Early in November, 1909, the moisture in the soil in ese plats was carefully determined to a depth of 4 feet. The sults of these determinations and several others are presented in the llowing table:

ABLE X.—*Results of determinations showing the percentage of soil moisture in the plats of alfalfa broadcasted and planted in drill rows and in hills having stands of varying thickness, Dickinson, N. Dak., November, 1909.*

Depth.	Broadcast.	Drills. 3 feet apart.	Hills. 16 by 16 inches.	Hills. 24 by 24 inches.	Hills. 18 by 36 inches.	Hills. 36 by 36 inches.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
rst foot	12.6	13.9	13.2	14.5	16.6	17.6
cond foot	9.7	11.9	13.7	14.7	15.5	16.8
hird foot	9.9	10.7	11.6	12.2	17.9	14.7
urth foot	8.4	14.5	12.4	16.1	18.8	18.7

It will be noted that in general the amount of moisture in the oil varies directly with the thickness of the plant covering, the hickly broadcasted plats having the least and the hills 18 by 36 nd 36 by 36 inches apart the most moisture. That a similar condition prevailed in the autumn of 1908 to that shown in Table X or 1909 can not be doubted.[a] Moreover, it seems likely that the ercentage of moisture in 1908 was much greater than in 1909, as he following comparison of the rainfall for the two years would ndicate:

	1908.	1909.
	Inches.	*Inches.*
eptember	1.67	0.83
October	2.47	1.08

The distribution of the rainfall in 1908 was such that a greater degree of saturation probably resulted than in 1909. September,

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[a] The soil moisture figures for both 1908 and 1909 are available for certain corn and wheat plats. The following percentages are the average for the top 3 feet of soil:

Corn.			Wheat.		
Date.	A.	B.	Date.	A.	B.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Oct. 21, 1908	21	21.4	Oct. 21, 1908	15.5	16.4
Nov. 11, 1909	14.8	14.6	Nov. 23, 1909	14.9	14.8

These plats received the same treatment both years.

1908, had eight days with rain; September, 1909, nine days. October, 1908, had six days with rain; October, 1909, had three.

The moisture determinations shown in Table X all relate to stands less than a year old. To determine whether similar conditions prevail in stands of greater age, with a varying thickness of the plant covering, 4-foot borings were also made in various places in the 1908 seedings. The results, which are corroborative, are presented in Table XI.

TABLE XI.—*Results of determinations showing the percentage of soil moisture in the 1908 experimental field plats and drill rows of alfalfa at Dickinson, N. Dak., in November, 1909.*[a]

Depth.	Thick stand. Plat 21217.	Thin stand. Plat 12784.	206 plants on 1,200 square feet.	171 plants on 1,200 square feet.	64 pl on 1, square
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per ce*
First foot	10.7	11.9	17.7	16.5	[illegible]
Second foot	9.7	11.7	13.2	14.0	[illegible]
Third foot	9.5	11.5	10.9	15.1	[illegible]
Fourth foot	8.3	11.4	11.1	15.6	[illegible]
Average	9.5	11.6	13.2	15.4	[illegible]

[a] The moisture determinations presented in Tables X and XI were made by Mr. John C. Thysell, through the courtesy of Prof. E. C. Chilcott, Agriculturist in Charge, Dry-Land Agriculture Investigations, Bureau of Plant Industry.

As in the case of the 1909 seedings shown in Table X, the quantity of moisture varies directly with the thickness of the stand, the area with the thinnest plant covering having on an average practically twice the amount of moisture of the thickest stand.

The thick and thin stands shown in the first and second columns of this table are located on Area IV, as shown in figure 1, and are adjacent. The Utah strain (S. P. I. No. 12784) was seeded in 190 and winterkilled badly during the winter of 1908–9, so that only about 15 per cent of a stand remains on this, the best portion of the plat. The commercial sand lucern plat was seeded in the spring of 190 and the portion on which the moisture determination was made has an estimated stand of 95 per cent. The determinations shown in the third column of Table XI are from borings made between drill rows 39 and 40 (commercial Turkestan and Wheeler's acclimatized Turkestan), as shown in Table XIII; those in column 4, between rows 51 and 52 (Minnesota and North Dakota Grimm); those in column 5, between rows 58 and 59 (two samples of commercial sand lucern from Germany).

It is evident from these differences in the amount of soil moisture that just comparisons in regard to the winterkilling of alfalfa can not be made in the future without taking the differences into account. If as appears likely, a higher moisture content produced a severer test dition, an accurate comparison of winterkilling can not be made ween the rows in question, as the ones with a thinner stand will ve been subjected to more trying conditions than the others. The ult of these moisture determinations also indicates that the pro- ssive thinning of a stand, which goes on more or less rapidly accord- to the hardiness of the strain used, is in itself a menace to the ccess of any field.

WEATHER CONDITIONS DURING THE WINTER OF 1908–9.

On November 25 and 26, 1908, no less than 7 inches of snow fell, t a severe blizzard on November 30 blew this into banks, leaving e alfalfa nursery, which is located on the north side of a shelter belt young, deciduous trees, practically bare of snow. On December 1 minimum of −10° F. was recorded. There was nothing particu- rly worthy of note in the weather of December, but as compared ith the same month in 1906 very little snow fell. In 1906 the total ll for the month was 7.5 inches, with a like amount on the ground at e end of the month, while in December, 1908, the total fall was 2.4 ches, with only 2 inches on the ground at the end of the month. In e alfalfa nursery, on account of the lack of a sufficiently dense plant vering to hold the snow, there was even less than this. This resulted the rows and hills having practically no snow covering to protect the lants.

Plate II, figure 1, illustrates more effectively than can be described he great importance of even a light covering of snow. The small atch of red clover seen in the middle of the foreground is all that emained on a series of plats immediately adjacent to the 1907 field lats of alfalfa. These plants have lived over without doubt as a esult of their being protected by 2 or 3 inches of snow. Extending long the right edge of the clover is the rather high ridge of another eason's back furrow, which held a sufficient crust of snow to prevent he extermination of this group of plants, while the loss on the emainder of the plats was 100 per cent. A similar phenomenon xplains the living over of the alfalfa plants, but in this case the rowth made during the previous autumn which was not removed erved to hold the snow. This point will be more fully discussed ater.

Table XII shows the complete weather record, except the wind direction and the character of the day, for January, 1909, at Dickinson. It is presented here to make possible a careful comparison of the weather of this month with that of January, 1907, which is shown in Table III.

TABLE XII.—*Daily record of temperature and precipitation for the month of Jan 1909, at Dickinson, N. Dak.; latitude, 46° 50′ N.; longitude, 102° 50′ W.; altit 2,453 feet.*

Date.	Temperature.				Precipitation.	
	Maximum.	Minimum.	Range.	Record at 6 p. m.	Snowfall.	Depth of snow on ground at time of observation.
	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	
1	23	−12	35	14		
2	39	2	37			
3	31	18	18	19		
4	20	−17	37	−16	0.2	
5	−16	−25	9	−20	.1	
6	−15	−31	16	−17		
7	− 8	−19	11	−16	.7	
8	−13	−25	12	−20	.1	
9	−15	−25	10	−19	.2	
10	−13	−21	8	−18	.2	
11	− 6	−28	22	−14		
12	6	−20	26	− 5		
13	− 3	−18	15	−10		
14	− 6	−20	14	−13		
15	0	−17	17	− 1	.7	
16	41	− 3	44	6	.5	
17	32	− 5	37	28		
18	41	21	20	26	[a] T.	
19	34	14	20	30		
20	41	28	13	40		
21	40	22	18	31		
22	34	31	3	33		
23	34	15	19	25		
24	34	18	16	27		
25	37	9	28	29		
26	36	19	17	29		
27	44	20	24	38		
28	37	3	34	12		
29	15	− 5	20	− 5		
30	12	−15	27	5		
31	38	4	34	26		
Sum	574	−82			2.7	
Mean	18.5	−2.6				

MONTHLY SUMMARY.

Temperature.

Mean maximum, 18.5° F.

Mean minimum, −2.6° F.

Mean, 7.85° F.

Maximum, 44° F.; date, 27th.

Minimum, −31° F.; date, 6th.

Greatest daily range, 44° F.

Snow.

Total fall, 2.7 inches; on ground 15th, — inches; at end of month, very little, and that in spots.

REMARKS.

Chinook on the 16th.

High winds on the 4th, 5th, 9th, 14th, 15th, 16th, 17th, and 19th of the month.

[a] T.—trace.

January, 1909, was the coldest month of a winter of normal temperature (13.8° F. for December, January, and February), during which all strains of alfalfa, including the very hardiest, winterkilled, from a few per cent to 100 per cent. January, 1907, on the other hand, was the coldest month of a winter of extraordinary severity, through which some plants of all strains, including the very tenderest, passed uninjured.

An inspection of Table XII shows that for a period of two weeks, extending from the 4th to the 17th of the month, the minimum temperature fell from −3° to −31° F. daily, while during one week of this period the maximum did not rise above −6° F. The snowfall for the month was light, amounting to 2.7 inches. There were seven or eight days with high winds, so that the small amount of snow that fell did not remain in place except where there was something adequate in the way of a plant covering to hold it. As a

lt of these winds the alfalfas had practically no snow to protect
m.

chinook, a climatic factor that is sometimes very trying to per-
ial crops and winter grains in this section, occurred on the 16th
he month. On this date the mercury rose rapidly from −3° to
F., a range of 44 degrees for the day.

he mean temperature for January, 1909, 7.8° F., was almost 12
rees higher than that for January, 1907, −3.9° F., and a trifle
re than 3 degrees lower than the normal for sixteen years. Hence,
ile this month was considerably warmer than the same month in
7, it was nevertheless colder than the average, and, considering
er climatic conditions, furnished a splendid test of the hardiness
alfalfa. The mean temperatures of February and March, 1909,
re higher than usual, as may be seen by an inspection of Table IV.
om February 7 to 15 the minimum temperatures ranged from
° F. on the 7th to −25° F. on the 14th. Fortunately for the
nts a snowfall of 5 inches occurred between these dates. No
ere winds to blow the snow into drifts were noted.

March weather was much less trying than that of 1907 and 1908.
1907 the range for this month was from −8° to 69° F.; in 1908,
m −17° to 54° F.; while in 1909 the lowest temperature was 7° F.
d the highest 58° F.

EFFECT OF WINTER OF 1908–9 ON ALFALFA VARIETIES.

The spring awakening in those strains that endured the winter with
y marked degree of success came about the usual time, beginning
ith the middle of April. In many strains whose mortality was
gh those plants that survived did not begin growing until a month
ter.

In order to make possible an accurate comparison of the resistance
cold of the sixty-eight strains used in the 1908–9 experiments,
able XIII is presented.

Table XIII.—*Results of experiments, showing the dead and living plants of alfalfa varieties sown in drill rows and hill rows, and the percentage of plants winterkilled at Dickinson, N. Dak., during the winter of 1908–9.*

Row No.	Number.	Source.	Drill rows.				Hill rows.				Combined proportion of winterkilling.
			Dead plants.	Living plants.	Total.	Winterkilled.	Dead plants.	Living plants.	Total.	Winterkilled.	
			Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Number.*	*Number.*	*Per cent.*	*Per cent.*
1	S. P. I. 21829	Deseret, Utah (second crop irrigated)	56	7	63	88.9	25	....	25	100.0	92.0
2	S. P. I. 21232	Mongolia (bulk lot)	14	46	60	23.3	6	19	25	24.0	23.5
3	P. L. H. 2124	Mongolia (large seed)	25	31	56	44.6	8	17	25	32.0	40.7
4	P. L. H. 2125	Mongolia (medium-sized seed)	23	35	58	39.6	8	17	25	32.0	37.3
5	S. P. I. 12784	Emery, Utah	46	10	56	82.1	23	2	25	92.0	85.2
6	S. P. I. 18627	Arabia	58	....	58	100.0	25	....	25	100.0	100.0
7	S. P. I. 18628	.....do	51	....	51	100.0	25	....	25	100.0	100.0
8	S. P. I. 21768	.....do	69	....	69	100.0	25	....	25	100.0	100.0
9	S. P. I. 21769	.....do	63	....	63	100.0	25	....	25	100.0	100.0
10	S. P. I. 21828	Deseret, Utah (first crop irrigated)	52	7	59	88.1	24	1	25	96.0	90.5
11	P. L. H. 3260	Yuma-Peruvian (second crop)	62	....	62	100.0	25	....	25	100.0	100.0
12	S. P. I. 13237	Chinook, Mont	57	11	68	83.8	18	6	24	75.0	81.5
13	S. P. I. 14972	Guaranda, Ecuador	57	....	57	100.0	25	....	25	100.0	100.0
14	S. P. I. 3507	Buenos Aires, Argentina	62	1	63	98.4	25	....	25	100.0	98.9
15	S. P. I. 3508	Mendoza, Argentina	55	....	55	100.0	23	....	23	100.0	100.0
16	S. P. I. 12549	Buenos Aires, Argentina	67	1	68	98.5	25	....	25	100.0	98.9
17	P. L. H. 3321	Baden, Germany	41	20	61	67.2	23	1	24	95.8	75.3
18	S. P. I. 9322	Tuggurt, Algeria	58	....	58	100.0	25	....	25	100.0	100.0
19	S. P. I. 12409	Diamond Fork, Utah (nonirrigated)	61	1	62	98.5	23	2	25	92.0	96.6
20	S. P. I. 12846	Kebilli, Tunis	62	....	62	100.0	25	....	25	100.0	100.0
21	S. P. I. 17992	Valencia, Spain	63	....	63	100.0	23	....	23	100.0	100.0
22	S. P. I. 21867	Nephi, Utah (dry land)	55	4	59	93.2	25	....	25	100.0	95.2
23	S. P. I. 12694	Provence, France	61	....	61	100.0	25	....	25	100.0	100.0
24	S. P. I. 12695	Poitou, France	59	....	59	100.0	21	4	25	84.0	95.2
25	S. P. I. 21195	Provence, France	59	....	59	100.0	25	....	25	100.0	100.0
26	S. P. I. 13259	Milburn, Nebr	49	10	59	83.1	23	1	24	95.8	86.7
27	S. P. I. 13857	Simbirsk, Russia	34	9	43	79.1	15	4	19	78.9	79.0
28	S. P. I. 991	Tashkend, Turkestan	43	4	47	91.5	15	2	17	88.2	90.6
29	S. P. I. 9359	Erivan, Russia	43	....	43	100.0	12	7	19	63.1	88.7
30	S. P. I. 9450	Askhabad, Turkestan	23	1	24	95.8	18	4	22	81.8	89.1
31	S. P. I. 9452	Karabulak, Turkestan	29	12	41	70.7	16	9	25	64.0	68.2
32	S. P. I. 9453	Bokhara, Turkestan	30	27	57	52.6	16	9	25	64.0	56.1
33	S. P. I. 13000	Tashkend, Turkestan	51	1	52	98.1	24	....	24	100.0	98.7
34	S. P. I. 14786	.....do	41	12	53	77.4	19	6	25	76.0	76.9

35	S. P. I.	18425	Commercial Turkestan									
36	S. P. I.	18751	.....do	15	29	44	34.1	22	2	24	91.7	
37	S. P. I.	19968	Samarkand, Turkestan	18	16	34	52.9	18	4	22	81.8	64.3
38	S. P. I.	20437	Tashkend, Turkestan	45	8	53	84.9	24	....	24	100.0	89.6
39	S. P. I.	21032	Commercial Turkestan	13	34	47	27.7	13	12	25	52.0	36.1
40	P. L. H.	3252	South Dakota (Tashkend, Turkestan)	1	49	50	2.0	6	19	25	24.0	9.2
41	S. P. I.	12747	Billings, Mont	14	32	46	30.4	17	8	25	68.0	43.7
42	S. P. I.	13436	Canada	14	40	54	25.9	17	8	25	68.0	39.2
43	S. P. I.	21247	.....do	16	22	38	42.1	16	8	24	66.7	51.6
44	S. P. I.	11651	Puèblo, Mexico	35	5	40	87.5	19	3	22	86.4	89.1
45	S. P. I.	11652	Guanajuata, Mexico	30	9	39	76.9	21	3	24	87.5	80.9
46	S. P. I.	11275	Commercial (bought in Chicago)	34	14	48	70.8	24	1	25	96.0	79.4
47	S. P. I.	12398	Fort Collins, Colo	40	7	47	85.1	22	3	25	88.0	86.1
48	S. P. I.	12671	Lawrence, Kans	35	6	41	85.4	21	4	25	84.0	84.8
49	S. P. I.	12816	Chinook, Mont	35	19	54	64.8	21	4	25	84.0	70.9
50	S. P. I.	12820	Clearwater, Nebr	32	18	50	64.0	18	7	25	72.0	66.7
51	S. P. I.	21938	Excelsior, Minn. (Grimm)	4	42	46	8.7	1	24	25	4.0	7.0
52	P. L. H.	3235	Fargo, N. Dak. (Grimm)	1	46	47	2.1	1	22	23	4.3	2.8
53	S. P. I.	21945	Sextorp, Nebr. (dry land)	36	13	49	73.5	20	5	25	80.0	75.7
54	P. L. H.	3251	Highmore, S. Dak. (Baltic)	18	35	53	34.0	9	16	25	36.0	34.6
55	P. L. H.	3255	Nephi, Utah (dry land)	44	10	54	81.5	23	2	25	92.0	84.8
56	P. L. H.	3256	.....do	50	7	57	87.7	21	4	25	84.0	86.6
57	S. P. I.	21187	France (commercial sand lucern)	32	24	56	57.1	19	6	25	76.0	63.0
58	S. P. I.	21217	Germany (commercial sand lucern)	30	22	52	57.7	21	3	24	87.5	67.1
59	S. P. I.	21269	.....do	43	7	50	86.0	23	2	25	92.0	88.0
60	S. P. I.	20896	France (commercial sand lucern)	50	6	56	89.3	20	2	22	90.9	89.7
61	S. P. I.	22416	Piedmont, Italy	51	....	51	100.0	24	1	25	96.0	98.9
62	S. P. I.	22417	Germany (Provence strain)	56	1	57	98.2	25	....	25	100.0	98.8
63	S. P. I.	22418	Germany (commercial sand lucern)	50	7	57	87.7	21	4	25	84.0	86.6
64	S. P. I.	22558	Gunnison, Utah (irrigated)	49	8	57	85.9	24	1	25	96.0	89.0
65	S. P. I.	22559	Gunnison, Utah (dry land)	41	4	45	91.1	25	....	25	100.0	94.3
66	S. P. I.	12803	Setif, Algeria	40	16	56	71.4	24	1	25	96.0	79.0
67	S. P. I.	20988	Commercial Turkestan	17	37	54	31.5	23	2	25	92.0	50.6
68	P. L. H.	3346	Richardton, N. Dak	31	6	37	83.8	25	....	25	100.0	90.3

The thirty-four varieties named in the first half of this table, comprising the east section of the nursery, are shown in Plate I, figure 2 (frontispiece), just back of the middle-ground. The photograph was taken June 10, 1909. Row No. 1 is designated by the white stake to the left of the figure 1 in the plate, and extends from this stake to the one next to the figure 35. The latter designates the row of this number. The stake labels stand at the head of the rows, or east end, while the photograph was taken from the foot of the rows of the west section, which comprises the varieties shown in the second part of Table XIII. The stakes scattered about in both the east and west sections indicate plants that were marked in the autumn of 1908 for work in selection and studies in correlation. The stakes appearing beyond the row from 1 to 34 are in another section of the nursery started in 1909, which is not a part of the present discussion.

In September, 1908, the number of living plants in both the hill and drill rows was determined by actual count. This count was made with very great care, and no row was left until the person counting was certain of the correctness of the count. On June 15 another count was made of the living and the dead plants in all rows and this was compared with the count of the previous autumn. In this way the percentage of winterkilling for the various strains was secured, as shown in Table XIII.

The loss of the sixty-eight strains may be summarized as follows:

12 strains killed out, 100 per cent.
16 strains killed out, 90 to 99 per cent.
14 strains killed out, 80 to 90 per cent.
7 strains killed out, 70 to 80 per cent.
5 strains killed out, 60 to 70 per cent.
4 strains killed out, 50 to 60 per cent.
2 strains killed out, 40 to 50 per cent.
4 strains killed out, 30 to 40 per cent.
1 strain killed out, 20 to 30 per cent.
2 strains killed out, 5 to 10 per cent.
1 strain killed out, 1 to 5 per cent.

For the sake of convenience the winter resistance of the strains under experiment will be taken up on the basis of their immediate geographical origin, as shown in Table IX, although this may lead in some cases to combining in one group several things that differ materially, both physiologically and botanically.

NTER RESISTANCE OF ALFALFAS IN DRILL ROWS AND HILLS IN THE 1908–9 EXPERIMENTS.

ALFALFAS FROM SOUTH AMERICA.

Five alfalfas from South America showed an average mortality 99.6 per cent. These strains were known to be nonhardy but were luded in the experiment for purposes of comparison. The Peru- an, P. L. H. No. 3260, which lost 100 per cent, was grown at Yuma, iz., from the original S. P. I. No. 9303, described in Bulletin 118 this Bureau. By reference to Table I it will be seen that 1 and per cent of No. 9303 endured the severe winter of 1906–7 at Dickin- n. This same strain suffered a loss of only 12.8 per cent of its and at Stockton, Kans., during the winter of 1908–9.

The strain from Ecuador is the famous Guaranda alfalfa, a short count of which also occurs in the bulletin cited. It is practically entical with the Peruvian and was completely killed out at Dickin- n, N. Dak., while at Stockton, Kans., the average loss of two uaranda samples was 10.6 per cent.

The Argentine samples resemble the foregoing in some respects, ut on the whole their affinities are more strongly toward the Chilean pe represented by our own Utah and California sort.

ALFALFAS FROM AFRICA.

Rows 18 and 20 (S. P. I. Nos. 9322 and 12846, respectively), which illed out 100 per cent, are the highly prized Oasis alfalfa of the ahara. The tenderness to cold of the Oasis variety will confine its sefulness to the warmer parts of the Southwest, where it is of promise ecause of the fine quality of its hay. It winterkills severely as far outh as Kansas, as may be seen from Plate II, figure 2, which is more ully described later in discussing the strain from Arabia. The hotograph used for this illustration was taken on the farm of Mr. C. Bartholomew, near Stockton, Kans. The experiments there, as ell as those at Dickinson, showed that merely living through the inter is not a sufficient recommendation for the use of a certain train of seed. The variety must be so hardy that it will emerge rom winter fit to take advantage of the first growing temperatures f spring. Nonhardy individuals of Oasis alfalfa No. 12846, the row hown in the middle of the picture, severely injured by the mild inter, did not recover sufficiently to begin a visible growth until a month later than the more resistant individuals. Of this strain 51.5 per cent killed out at Stockton and 100 per cent at Dickinson. No. 9322 did not suffer as severely in comparison, losing 35.2 per cent at Stockton, while at the northern station its loss was also 100 per cent.

The third North African strain (S. P. I. No. 12803, row 66) is t one grown in rows at Setif, Algeria, and referred to in a precedi footnote (pp. 9–10) of this paper. Seventy-nine per cent of the pla of this variety, which appears very similar to the Poitou alfalfa France, winterkilled. The average number of plants winterkil for the three African strains at Dickinson was 93 per cent.

ALFALFAS FROM EUROPE.

There were included in the experiment 15 samples from Europe sources. The average loss of plants for all strains was 87.9 per cen

	Per cent.
2 Russian strains lost an average of	83.9
5 German strains lost an average of	83.1
5 French strains lost an average of	89.6
1 Italian strain lost	98.7
1 Spanish strain lost	100
1 commercial strain lost	79.5

One of the German strains (row 17, P. L. H. No. 3321, which occurs in the inventories of the Office of Foreign Seed and Plant Introduction under Nos. 22467 [a] and 24767 [b]) is of sufficient interest to deserve a preliminary note in the present connection. This strain is known as "alt-deutsche fränkische Luzerne," and all evidence thus far secured points to its being the progenitor of the highly esteemed Grimm alfalfa, which is mentioned later in these pages. It takes its name from the circles of Franconia in northern Bavaria, and the present sample was secured only a few miles from the ancestral home of Wendelin Grimm, who introduced alfalfa into Minnesota in 1857. It is interesting to note that this strain has the same distinctive habit of growth as the Grimm.

The appearance of a majority of the rows of European alfalfa, or lucern, after the winter of 1908–9 is shown in Plate III, figure 1. The old German variety previously mentioned is row 17 and can be seen best in Plate I, figure 2 (frontispiece). It forms the continuation of the right-hand row of Grimm alfalfa near the center of the picture. Row 46 (S. P. I. No. 11275), a commercial sample purchased in the open market, appeared from its botanical characteristics to be of European origin. The seedsmen who furnished it state that it was purchased from an Italian source. This number suffered to the extent of 79.5 per cent. It resembles strongly S. P. I. No. 12803 from Setif, Algeria (row 66).

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[a] See "Seeds and Plants Imported during the Period from January 1 to March 31, 1908," Bulletin 137, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 56–57.

[b] See "Seeds and Plants Imported during the Period from January 1 to March 1, 1909," Bulletin 162, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 42.

ALFALFAS FROM ASIATIC SOURCES.

ARABIA.

The discussion of the strains from Asia falls naturally into three oups. Taking up first the Arabian strains, rows 6, 7, 8, and 9, eir loss was 100 per cent for each of the four numbers. As far south Stockton, Kans., these same numbers killed out 100 per cent, ough the winter there was an extremely mild one. The condition these rows at Stockton on June 1 is shown in Plate II, figure 2. e two rows in the middle of the picture showing a certain percentage living plants are African strains, the one having the better stand ing identical with Dickinson row 20, Kebilli Oasis alfalfa (S. P. I. o. 12846), while the other is from Tripoli (S. P. I. No. 12847). The irs of rows on either side are the Arabian numbers.

TURKESTAN.

Among the twelve strains listed as from Turkestan three were prouced in the United States from Turkestan seed of known origin. . P. I. No. 13999 (row 33) was grown on unirrigated land in Utah n 1904 from S. P. I. No. 991 (see row 28), which was sown in 1900; . P. I. No. 19968 (row 37) was grown in Kansas in 1906 from S. P. I. No. 1295, from Samarkand, sown in 1899. S. P. I. No. 20437 (row 8) was produced in 1906 by the same field as No. 13999, noted above. The average loss in stand of these three numbers was 84.3 per cent.

Inasmuch as practically all of the Turkestan seed used by American armers comes from a great range of unknown conditions of soil and limate under the commercial name "Turkestan," four samples purhased in the open market were included in the experiment. These samples are rows 35, 36, 39, and 67. The average winterkilling of the strains was fairly low, 58.6 per cent, but the range was from almost 36 per cent (row 39) to almost 93 per cent (row 35). When one considers that Turkestan has an area almost as great as that part of the United States lying west of the Mississippi and a climate that ranges from as cold as Montana to as hot as Arizona, this range in the hardiness of commercial samples of seed is not surprising. It suggests also the danger confronting the northern grower who purchases seed whose only recommendation is that it came from Turkestan.

The last class of Turkestan strains includes five secured from known sources. These came from a considerable range of territory, extending from Askhabad, in the southern part of the Transcaspian district, northeastward through Bokhara and Tashkend and northwest to Karabulak, north of the Aral Sea. It is a matter of regret that no sample from Verni, which is said to be the coldest alfalfa-producing section of Turkestan, was included in this experiment. In the new

MEXICO.

The average winterkilling of the Mexican rows 44 and 45 (S. P. Nos. 11651 and 11652) was 85 per cent. The original source of th strains is unknown, but their immediate geographical origin wo have led one to expect a higher percentage of loss. Rows 44 and 4 are shown in Plate IV, figure 1, next to the Canadian numbe In habit of growth, leafage, etc., they resembled considerably so of the Turkestan strains.

UNITED STATES.

Among the strains attributed to this country two classes must b recognized: (1) Those that are without doubt ordinary Americ alfalfas of the Chilean type, of which there are eighteen numbers, an (2) those that are clearly the progeny of introductions from the Ol World. Of the latter there are only four (rows 40, 51, 52, and 54) but among them are the alfalfas of the greatest present importanc to agriculture in the cold parts of the United States.

ORDINARY AMERICAN ALFALFA.—Ordinary American alfalfa, which came to the United States from Chile, has often proved not sufficiently hardy for our severe northern climate. The average winterkilling of the eighteen strains included under this head was 83.3 per cent. The greatest mortality is found in three of the Utah dry-land strains, as follows:

	Per cent.
Row 19, S. P. I. No. 12409, Diamond Fork, Utah	96.6
Row 22, S. P. I. No. 21867, Nephi, Utah	95.2
Row 65, S. P. I. No. 22559, Gunnison, Utah	94.3
Average	95.4

The hardiest strain of ordinary American alfalfa was a Montana strain (row 41, S. P. I. No. 12747). This seed was produced in the Yellowstone Valley near Billings, where it had been grown for a number of years. This sample suffered to the extent of 43.7 per cent.

Next to the above in hardiness was the sample from Clearwater in north-central Nebraska, row 50, S. P. I. No. 12820. This number suffered to the extent of 66.7 per cent. These and several other American strains are shown in Plate IV, figure 1 (rows 41, 47, 48, 49, and 50).

Only two other strains of this class showed a degree of hardiness that entitles them to mention. These strains and the proportion of the plants winterkilled are as follows:

	Per cent.
Row 49, S. P. I. No. 12816, Chinook, Mont	70.9
Row 53, S. P. I. No. 21945, Sextorp, Nebr	75.7

The latter is a highly esteemed dry-land form grown by Mr. Lewis Brott on the high plains of western Nebraska. Unlike the Utah dry-nd strains this one is grown in a section that is subject to decidedly w temperatures at times, with little or no snow covering to protect ant growth. The normal autumn rainfall in this section is very ht.

The question whether American alfalfa of the ordinary sort has ndergone any change in hardiness since its introduction, about 55, has been discussed recently by alfalfa breeders and growers. o experimental evidence bearing on the point has been published retofore. Hence, the results obtained in the present experiment hile by no means conclusive are of more than ordinary interest.

The eighteen strains of ordinary American alfalfa showed a great fference in hardiness, as winterkilling under the uniform condions of the experiment ranged from about 44 per cent (row 41) to most 97 per cent (row 19). The mere presence of so high a degree diversity with reference to one physiological character is extremely ggestive.

Botanically, alfalfa or lucern (*Medicago sativa*) is an exceedingly iverse species composed of numerous strains, varieties, or possibly bspecies. Even the most uniform of our cultivated sorts, such as e Peruvian and Arabian, comprise numerous strains that are sily recognizable on inspection. Ordinary alfalfa, of course, shares the diversity common to the species as a whole. That some of hese component lines or individuals are more susceptible to cold han others seems axiomatic. Resistance to cold would then depend rgely at least on the severity of the climate to which a strain has een subjected; that is, to the amount of "weeding out" of unfit nes and individuals that has taken place.

The selective value of the Montana climate with reference to ardiness is unquestionably greater than that of Utah or most of ebraska; in fact, it does not seem unfair to suppose that that of orthern Nebraska is superior to that of Kansas.

Different winters have different selective or acclimatizational alues with reference to various test factors. Very severe winters ith heavy snows that remain in place have small selective effect; ild winters with even a moderate snowfall, such as that of 1907–8 t Dickinson, have practically no effect on strains having only the ustomary degree of hardiness. Tender sorts, like the Arabian, Peruvian, Tunisian, and Tripolitan, are susceptible of selection with ven comparatively mild winters, such as that of 1908–9 at Stockon, Kans.

The following statement shows by States the average winterkil of common alfalfa in the row and hill experiments at Dickinson:

	Strains.	Per cent.
Utah	[a] 10	90.4
Colorado	1	86.1
Kansas	1	84.8
Nebraska	3	76.4
Montana	3	65.4

The number of strains from the different States is too small use as a basis for generalization, but it is hoped that the data h given will lead other investigators to make a careful record of res of similar experiments.

Progeny of Old World Introductions.—It is among progeny of alfalfas introduced from the Old World that we find highest degree of hardiness, a degree of hardiness that in at le one case might almost be called wonderful.

Each of the four numbers included in this class emerged from winter of 1908–9 with a notably high percentage of living plan Their combined average loss is 13.5 per cent, while the percenta of loss for the individual strains were as follows:

Table XIV.—*Results of experiments showing the percentage of winterkilled al plants of four strains introduced from the Old World.*

Row No.	Accession No.	Source.	Prop tion wint kille plant
			Per c
52	P. L. H. 3235	Fargo, N. Dak. (Grimm) (originally from Baden, Germany)	
51	S. P. I. 21938	Clearwater, Minn. (Grimm) (originally from Baden, Germany)	
40	P. L. H. 3252	Highmore, S. Dak. (originally from Tashkend, Turkestan) (S. Dak. No. 240).	
54	P. L. H. 3251	Brookings, S. Dak. (S. Dak. No. 167. Original source not known, but probably from Europe).	
		Average	1

Grimm alfalfa.[b]—Grimm alfalfa, which is named after Wend Grimm, the German immigrant by whom it was introduced, is t hardiest form of the cultivated plant known at the present time. progenitor was brought to Minnesota in 1857 from Külsheim, betwe Wertheim and Tauberbischofsheim, in the valley of the Tauber Baden, Germany.

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[a] This includes row 18, common alfalfa which endured the mild winter of 1907- in North Dakota.

[b] A short account of the history and probable method of development of Grim alfalfa by the senior writer of this bulletin has been published, entitled "The Acc matization of an Alfalfa Variety in Minnesota," Science, n. s., vol. 28, Decemb 1908, pp. 891-892.

The drainage basin of this little stream, which empties into the ain at Wertheim, known as the Taubergrund, is at the present time e chief seat of the production of seed of "alt-deutsche fränkische zerne" (row 17), already mentioned in these pages. This strain of alfa is highly prized in Germany and appears to have been under ltivation in the old Franconian circles of Baden, Württemberg, and varia for several hundred years.

The two Grimm strains included in the present experiment proved be the hardiest of the sixty-eight under observation. The hardier e, P. L. H. No. 3235 (row 52), was produced in 1904 on a plat about years old on the farm of the North Dakota experiment station. is seed was presented to the Department of Agriculture in October, 04, by Prof. J. H. Shepperd, vice-director and agriculturist. This rain lost less than 3 per cent of the plants in hill and drill rows com- ned. Only one plant of twenty-five in the hills, which are 2½ feet art in the row with the rows themselves 3 feet apart, succumbed ring the winter. In the 50-foot drill row only one plant out of rty-seven was killed.

Second in hardiness was a Minnesota-grown strain of Grimm alfalfa, . P. I. No. 21938 (row 51). This seed was secured from Mr. A. B. yman, of Excelsior, Minn. It was produced near Clearwater, tearns County, from Carver County seed. In the hill row one plant twenty-five winterkilled, in the drill row four out of forty-six, the verage loss for both being 7 per cent.

As an indication of the vigor that the Grimm alfalfa had after assing through the winter of 1908–9, which was so destructive to rdinary alfalfas, mention may be made of the yield of seed from a enth-acre plat of Grimm grown just adjacent to the experiment nder consideration. This plat was sown in the spring of 1908 in ows 3 feet apart and kept cultivated. The plants were quite thick in he row. A clipping was made of this plat in 1909 early in the season, hen it had attained a growth of about 8 inches. It was not cut gain until September 28, when a cutting was made for seed. The lat yielded 33.6 pounds of clean seed, which is at the rate of 336 ounds, or 5.6 bushels, per acre. This is certainly an admirable howing.

If, as appears likely, the old German Franconian lucern (row 17) is he progenitor of the Grimm, we have here a further suggestion as to he possibilities of habituating alfalfa to a new or foreign climate. he loss of the former was over 75 per cent, the average for two trains of Grimm less than 5 per cent.

Acclimatized Turkestan alfalfa.—Plant Life History No. 3252, row 40 (S. Dak. No. 240), was produced at Highmore, S. Dak., by Prof. W. A. Wheeler, from Prof. N. E. Hansen's original introduction of

Turkestan alfalfa from Tashkend (see row 28), S. P. I. No. 991. I Bulletin 101[a] of the South Dakota Agricultural Experiment Stati Professor Wheeler has given a short account of this strain, a part which is as follows:

> No. 240. Seed was obtained from the United States Department of Agriculture und S. P. I. No. 991. This was collected (obtained) by Prof. N. E. Hansen at Tashke Turkestan, in 1898. It has been grown in plots at Highmore since 1899 and apparen has not killed out. This is a severe test of its resistance to both cold and drough A small plot has been cut for seed in both 1905 and 1906 and some seed has bee obtained. So far, it does not appear to be nearly as good a seed producer as any Nos. 162,[b] 164,[c] or 167,[d] but it can not be compared with these until it has go through as many generations from seed in this State as have the other three numbe cited. This alfalfa is thought to be of the same introduction as No. 164. If this correct it will probably become a better seed producer after it has been grown fro several seed-producing generations in this State. The quality of this number is abo the same as No. 164. This ranks as one of the four best alfalfas which have been tri at Highmore.
>
> Numbers 162, 164, 167, and 240 are hardy and are possessed of high forage qualities, so that they can be recommended for the conditions under which they have bee tried. Numbers 162 and 167 start earlier in the spring and produce a stronger and more vigorous first crop than numbers 164 and 240. With the second crop this differ-ence is not so noticeable. These four numbers have been tested from eight to ten years in this State and with the exception of number 240 have gone through several generations from seed. The fact that they have reproduced from seed through several generations seems to have more to do with acclimating alfalfa than has the mere fact that they have grown so many years under these conditions from a single seeding. This is where No. 164 leads over No. 240. * * *
>
> For the present the work will be restricted entirely to selected stocks from Nos. 162, 164, and 167. Work with No. 240 progresses more slowly because of its poorer seed production.

An examination of the published station records shows that although No. 240 has been grown at Highmore since 1899, even approximately accurate data concerning its behavior have been taken only since 1903.

The seed used in the Dickinson experiments was produced in 1905, the seventh year from seeding. This acclimatized Turkestan strain ranked third in hardiness among the sixty-eight strains tested, and appears to show that the parent strain had become profoundly changed in cold endurance by the seven winters spent in South Dakota. This change probably resulted from the successive eliminations of the unfit lines of descent.

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[a] Wheeler, W. A., and Balz, Sylvester. Forage Plants at the Highmore Substation, 1906. Bulletin 101, South Dakota Agricultural Experiment Station. March, 1907.

[b] This number is the Grimm alfalfa of Minnesota, grown for several years at Brookings and Highmore.

[c] No. 164 is supposed to be the progeny of the same number (S. P. I. No. 991) as the present sample, P. L. H. No. 3252. No. 164 was produced from No. 991 sown at Brookings in 1898, while No. 240 was produced from No. 991 sown at Highmore in 1899.

[d] No. 167 is the parent of P. L. H. No. 3251 (row 54 at Dickinson).

This strain of Turkestan alfalfa which underwent seven years nat- ral selection in South Dakota presents an opportunity for several nportant comparisons. These are not presented as final in any nse, but rather to stimulate further investigation.

Row 28 was seeded with a small quantity of seed remaining from e original lot of S. P. I. No. 991, the first importation from Turkes- n. Row 40 is the South Dakota progeny of No. 991. Rows 33 nd 38 are the Utah progeny of the same number. Both were har- ested from the same field which was seeded down in 1900. Row 33 as harvested in 1904, row 38 in 1906.

Table XV shows the comparative winter resistance at Dickinson f No. 991 and its Utah and South Dakota progeny.

ABLE XV.—*Comparison of Turkestan alfalfa, S. P. I. No. 991, with certain strains grown from it, showing the percentage of plants winterkilled.*

Row No.	Accession No.	Source.	Proportion of plants winter-killed.
			Per cent.
28	S. P. I. 991	Turkestan (imported 1898)	90.6
40	P. L. H. 3252	Highmore, S. Dak. (1899–1906)	9.2
38	S. P. I. 20437	Wellsville, Utah (1900–1906)	89.6
33	S. P. I. 13999	Wellsville, Utah (1900–1904)	98.7

The distance between row 28, the original stock, and row 33, the 1904 progeny, is only 15 feet, while that between rows 38 and 40 is nly 6 feet. All conditions were uniform so far as known, and still his great diversity appears. The greater age of the original seed might be responsible for some of the difference in hardiness between his and the South Dakota-grown strain. But here we are confronted with the fact that the 1904 progeny from Utah—comparatively fresh eed—suffered even more than the foundation stock, while the 1906 rop suffered an almost equal loss. It is not possible in the limits of he present paper to discuss, nor is there sufficient data to warrant iscussing, the numerous biologic factors that may be concerned in hese diversities.

The differences in loss in the 1904 and 1906 Utah strains suggest at the two additional winters endured by the latter may have had eater selective value than those from 1900 to 1904. It appears om the records that this was the case. The lowest temperature that curred during these years at Logan, Utah, the nearest point to Wells- ille having a temperature record, was −17° F. on February 14, 1903; ut on the 11th and 12th of the month more than 2 inches of snow had llen, and the observer makes the comment that "fields were gener- lly well covered with snow throughout the month, and it is therefore not probable that any damage was done to fall grain by low tempe atures."

The minimum temperature during the winters of 1904–5 and 1905– was −15° F., which occurred in both winters. The minimum of th former fell on February 12. Between January 1 and February 1 almost 2½ inches of rain had fallen. This no doubt resulted in a saturated condition of the soil that led to considerable injury to the plant when 15° F. below zero weather occurred on the 12th. January ha been a warm, balmy month that tended to stimulate new growth i the plants.

The minimum temperature of the winter of 1905–6 (−15° F.) fe on January 8. Two inches of snow had fallen during the last day of December. This probably gave enough protection from the cold.

The seeding capacity of this strain, P. L. H. No. 3252, is not satisfactory according to Professor Wheeler; however, it is scarcely mor than axiomatic to state that the seed production may be improved by the selection of those lines within the strain that produce seed better than the average of the strain. If we assume that the various lines within the strain remain constant from generation to generation, then we are not modifying the alfalfa in any other way when we improve its seed production. We are merely isolating those lines of high seed production. The strain is merely in the process of purification. On the other hand, it is not at all unlikely that mutations, of greater or less moment, are more or less constantly taking place within the strain. In such a case it would be quite proper to speak of the alfalfa as being modified, though such modifications would be almost purely spontaneous. In other words, we have not progressed enough in the science of breeding to be able to bring about desired mutations at will. The function of open pollination in alfalfa breeding is something about which we have almost no exact knowledge.

One difficulty in interpreting the results from the different sowings from No. 991 is that we are not well enough posted as to the previous history of the imported seed. The following statement concerning it is found in Inventory No. 1 of the Section of Seed and Plant Introduction:

991.[a] MEDICAGO SATIVA. **Alfalfa.**

From Tashkend. Received through Prof. N. E. Hansen, June 4, 1898. (200 bushels.)

Variety "*turkestanica*." This subspecies of alfalfa was obtained from eight different sources varying widely in climatic conditions. It endures droughts which kill European alfalfa. Deemed very promising for trial in droughty regions. See No. 469.

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[a] Foreign Seeds and Plants Imported by the Section of Seed and Plant Introduction. Inventory No. 1, 1898, p. 81.

9.[a] MEDICAGO SATIVA. **Alfalfa.**

From Turkestan Agricultural Society, Turkestan. Received through Prof. N. E. Hansen, March, 1898.

lative alfalfa. Endures drought better than European alfalfa.

Rows 28, 38, and 33 run reasonably close together in hardiness. e deviation is perhaps no greater than would be expected from y run of commercial seed. Whether the seed from the eight iginal sources was mixed or not, a reasonable hypothesis would be at some of the hardier seed was planted in South Dakota. Even is seed was probably a mixture representing more or less hardy rains. By the result of natural selection the hardiest lines or rains were brought to the seeding stage in South Dakota and then ansferred to Dickinson. It is an interesting fact that No. 991 was idently imported more for its drought resistance than for any tential hardiness.

South Dakota No. 167.—Although the source from which the strain seed, South Dakota No. 167, originally came is unknown, it is vious from its botanical characteristics that it is of European igin.[b] The name Baltic was first applied to it in 1906 by Prof. . A. Wheeler, formerly botanist to the South Dakota Agricultural ollege and Experiment Station, from the fact that it had been rown for about ten years near the little village of Baltic in Minneaha County, S. Dak., and not as has been supposed in the Baltic Sea gion of Europe.

The appearance of this strain, which is P. L. H. No. 3251, in the pring of 1909 is shown in Plate III, figure 1, row 54. Although howing a promising degree of hardiness, at Dickinson this strain as the tenderest of the four hardy American races derived from the ld World introductions. In the drill rows, where it is possible that he thicker stand by binding more snow may have been afforded lightly more protection, the loss was 34 per cent, while in the hill rows, where the plants were subjected to the severest test, the loss was 36 per cent. It may be of interest to state that the entire nursery killed out 2.3 per cent more than did the plants in the drill rows.

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[a] Op. cit., p. 42.

[b] Mr. J. M. Westgate, of the Office of Forage-Crop Investigations, first directed attention to the probable European origin of this alfalfa. Mr. Westgate noted the very interesting fact that several European alfalfas show greater diversity in flower color than o our ordinary American or the Turkestan types. In the Dickinson experiments he diversity is about equal in the Grimm samples (rows 51 and 52), South Dakota No. 167, the so-called Baltic alfalfa (row 54); "alt-deutsche fränkische Luzerne" (row 17); commercial or false sand lucern, No. 20896 (row 60); and first-quality commercial alfalfa, probably from Italy, No. 11275 (row 46). It occurs to a less degree in Simbirsk alfalfa, No. 13857 (row 27); in Poitou alfalfa, No. 12695 (row 24); Italian alfalfa, No. 22416 (row 61); and Algerian alfalfa, No. 12803, from Setif (row 66). At Stockton, Kans., a very similar degree of diversity in color was found in Italian alfalfas, Nos. 12696 and 13481. A much greater variegation in color was found to exist in commercial sand lucern, Nos. 21187, 21217, 21269, and 22418 (rows 57, 58, 59, and 63), though the last number showed less diversity than the other three.

Climatic conditions at Highmore, S. Dak. (altitude 1,860 feet), where the seed generation used in the present experiments was produced are no doubt less severe than at Dickinson (altitude 2,453 feet) which is located about 300 miles farther northwest on the Great Plains. Professor Wheeler found the Baltic alfalfa very promising at both Highmore and Brookings and published his observations in Bulletin 101 of the South Dakota station, already cited. His notes are of sufficient interest to be quoted in full, as follows:

> No. 167. The original source from which the seed of this number was introduced into this country is unknown. Mr. W. F. Kelly, of Renner, S. Dak., purchased the seed about ten years ago from a seed dealer at Hartford, S. Dak. He and Mr. E. C. Evans of the same place have grown it for about ten years and consider it better than other alfalfas tried in their vicinity. Mr. Kelly furnished several pounds of seed to the Agricultural College in 1905. A two years' trial of the variety is rather short upon which to draw conclusions. In all our tests, however, both at Highmore and Brookings, this number has shown itself equal to any in quality, hardiness, and seed production. It has not been sown in the selection rows and so has not been put to quite so severe a test of hardiness as No. 162 (Grimm alfalfa), and as there is no record of its having been tested under northern conditions in the past, as has No. 162, it cannot be compared in hardiness to the latter number. In seed production it is equal if not superior to No. 162. In quality and the vigor of early spring growth it appears to be equal.

The test in the nursery rows at Dickinson was probably more severe than any this strain had previously endured. Hence, although not the equal of a few other strains it is decidedly valuable. It ranked fifth among the sixty-eight strains at Dickinson. Of the new introductions only one, Mongolian No. 21232, excelled it in winter resistance. It ranked high as a seed producer at Dickinson in 1909.

COMPARISON OF CONDITIONS IN FIELD PLATS AND IN ROWS AND HILLS.

The hill and row experiment just discussed represents the severest possible test of the winter resistance of alfalfa for the weather conditions that prevailed while the work was in progress. Fortunately, the two small series of field plats already discussed, which are on a rather pronounced southern slope above the alfalfa nursery, offer in comparison what might be termed decidedly more favorable conditions than alfalfa is likely to be grown under in most years in this region. Except for January the winter of 1908–9 was no more severe than may be expected any year.

One set of the field plats containing four different strains was seeded in the spring of 1907. These plats should have been cut in ordinary farm practice twice during their second year, as it would ot pay to leave such a heavy stand of alfalfa on the field at the dvent of winter. They were cut only once (on July 20) and the econd growth was left on the ground to furnish winter protection. recipitation to the amount of 0.65 inch occurred during three loudy days preceding the cutting and a copious rain fell a few days fter the cutting. As a result, recovery was rapid and growth coninued until well into the autumn. Indeed, the growth of over two onths and a half remained on the ground.

The favorable conditions under which these plats entered the inter could scarcely be duplicated; they were in their second year, ad enjoyed ample moisture for continued growth through the season, ad been cut only once, and that in midseason, leaving a good stand o bind the snow. In spite of this the four varieties lost from 15 to 0 per cent of their stands, the loss varying greatly as we have seen n different parts of the plats. On June 10, 1909, a Turkestan strain from Tashkend, S. P. I. No. 14786, stood best of the four, followed losely by S. P. I. No. 13857 from Simbirsk, Russia. The loss in these strains based on careful estimates was 15 and 18 per cent, respectively. An irrigated strain from Utah (S. P. I. No. 12784) and one from Colorado (S. P. I. No. 12398) lost about 80 and 90 per cent, respectively. A slight portion of the loss in these two cases occurred in the mild winter of 1907–8, but most of it was due to the winter of 1908–9. The snow protection during the former was such that only the really tender kinds suffered even slightly. The other two strains, which were known to have a certain amount of hardiness, maintained full stands through the winter of 1907–8.

The nine other field plats were sown in May, 1908. This was an unusually favorable year for getting a stand of alfalfa. The nursery rows as well as the field plats shared in the beneficial conditions that prevailed, the latter in a higher degree than the former, as in dry or even ordinary years fields sown by the usual methods suffer considerable hindrance in growth because of a lack of moisture. This results in the autumn in an insufficient covering of vegetation to hold the snow that is necessary to furnish a winter protection to the plants.

April, 1908, had a little more than the normal rainfall. May, the month in which seeding was done, had a precipitation of 3.50 inches. This is more than an inch above normal and insured rapid germination and a good stand of young plants. June rainfall amounted to 4.30 inches, about 1½ inches above normal. This enabled the plants to become firmly established and to make a fine growth throughout July, when ¾ inch less than the normal amount of rain fell.

These plats were clipped a few days after a heavy rain that fell July 24 and about ten days earlier than the experimental rows in the nursery. They began a prompt recovery which was no doubt gradually retarded by a hot dry spell that lasted until August 12. The hill and drill rows, which together contained an average of about seventy-five plants of each variety, were cut on August 5 in the midst of this dry time. As no rain fell until August 12 they were at some disadvantage in making a recovery. The field plats, on the other hand, had already begun growth and were forced to harden their tissues to a considerable extent. The presence of this hardened tissue was a factor of undoubted value in wintering over.

During the second half of August the rainfall was ample; the shortage for the whole month amounting to less than ½ inch as compared with the 16-year normal. September's rainfall (1.67 in.) exceeded the normal more than ½ inch, while October's precipitation (2.47 in.) was over 1½ inches more than this month usually receives. The rainfall of these two months had opposite effects on the row and field experiments, affecting the former unfavorably and the latter favorably. This seems paradoxical, but really is not. In the first place because of their sidehill location and hard uncultivated topsoil, as compared with the rows, the run-off was greater from the field plats than from the nursery.

The moist autumn benefited the field plats by enabling them to make a late growth through the autumn. This increased their snow-holding capacity. At the same time on account of the run-off and the far greater transpiration from a thick stand, the dangers attendant upon an excess of moisture in the soil during the winter were avoided.

In the nursery rows the opposite was true. There was a sufficient growth of plants in height, but the stand was too thin to hold much snow. The bare ground, the distance between the plants, and the cultivation resulted in a dangerous saturation of the soil. In the final analysis it was found that the presence of excess moisture in the soil and the absence of snow covering killed the plants in the rows, and the presence of snow covering and the absence of excess moisture enabled the plants in the field plats to live. It was dry enough in the plats to cause the formation of hard tissue without intercepting growth and wet enough in the rows to cause a sappy growth to continue until hard frosts stopped growth altogether.

The season and treatment were such that when winter came the plants in the field plats had made ample growth to hold the snow. Thickness of stand combined with height increased the snow-binding capacity. The thick stand, conducive to a greater transpiration, and the topography of the field, which promoted the run-off, prevented an excess of moisture in the soil when cold weather came. The opposite was true in the case of the rows. Furthermore, the field plats have a warmer, more protected situation, due to a southern slope and the location below the brow of a ridge. The rows are ated near the base of this ridge in such a way that they are rather re exposed to the prevailing winter winds which come from the rthwest.

The row test is the severest to which alfalfa can be put in the area ich Dickinson typifies, but as this general region, which includes ge parts of North Dakota, South Dakota, and Montana, has a rmal rainfall of less than 18 inches, row cultivation of alfalfa may ove to be the best farm practice. If this proves to be the case, the alfa suitable for this area must be able to bear this rigorous test ccessfully.

The rainfall for September and October, 1908 (4.14 inches), while usual for Dickinson and all of the region west of the one hundredth eridian in the States just named, is normal in Minnesota, Wis-nsin, and Michigan, and not infrequently occurs in eastern North d South Dakota and, as was the case in 1898 and 1908, in the estern part of the Dakotas. The alfalfa for this region must be ured to this amount of autumn moisture followed by low tempera-res with or without snow.

The winterkilling of varieties on the 1907 and 1908 field plats has lready been discussed. It was found that there was a great diver-ty in loss on the thick and thin parts of the same plat. Where he stand was thin or inoculation poor, greater loss occurred. Ten f the varieties on the field plats were duplicated in the rows. In no ase was the loss as great in the former as in the latter, but the com-arative behavior in both cases was similar; that is to say, when anged in series on the basis of winterkilling, the duplicate strains ccupy a very similar relative position. The six strains that were hown to be the hardiest on the field plats rank in the following order: Montana Grimm, S. P. I. No. 21827; Nebraska Grimm, S. P. I. No. 21735; Turkestan, S. P. I. No. 20988; commercial sand lucern, S. P. I. No. 21217; Turkestan, S. P. I. No. 14786; Canadian, S. P. I. No. 21247.

In the rows where the test was severer, the ranking was as follows: North Dakota Grimm (row 52); Minnesota Grimm (row 51); Turkestan, S. P. I. No. 20988; Canadian, S. P. I. No. 21247; commercial sand lucern, S. P. I. No. 21217; Turkestan, S. P. I. No. 14786. Only the Canadian strain in the field plats fails to show the same relative strength. This is probably due to the unsubdued condition of the soil on this plat, which was new breaking, as well as to the original thinness of the stand, and not to any greater inherent weakness in the strain. Among the four weakest strains, in which the loss in the rows ranges from about 80 per cent up, the agreement is not so close.

From this it is apparent that we are dealing not so much with a difference in the hardiness of the varieties under comparison, but merely with differences in the amount of loss under tests of varying severity. Some of the factors that contributed to the greater loss in the nursery rows as compared with the thickly seeded plats may be summarized as follows:

(1) The 1907 field plats were cut between two rains, two weeks earlier than the rows; the 1908 plats were cut about ten days earlier than the rows and a few days after a good rain; the rows were cut August 5 in the midst of a hot dry spell that lasted over two weeks, the most protracted of an otherwise unusually favorable season for growing alfalfa.

(2) The field plats had a thick growth which by transpiration aided in exhausting excess moisture from the soil before winter came and later, together with weeds, furnished lodgment for a protective covering of snow that acted like a blanket in shielding the plants from cold.

(3) The field plats have a warmer, more protected situation, due to their location on a pronounced southern slope and below the brow of a ridge. The rows are located near the base of this ridge in such a way that they are more exposed to the prevailing winter winds which come from the northwest. This slope, by promoting the run-off, further aided in preventing the saturated condition of the soil, which undoubtedly acted disastrously on the nursery rows.

FURTHER OBSERVATIONS ON THE EFFECT OF AUTUMN MOISTURE.

In the preceding pages much emphasis has been placed on the injurious influence of autumn moisture on the wintering over of alfalfa. In order to determine whether similar losses have occurred in other experiments the alfalfa work of the North Dakota, South Dakota, and Minnesota stations has been studied especially. The winter of 1898–99 was one noted for its extremely low temperatures in the Great Plains region. At Brookings, S. Dak., the experiment station had a plat of the original importation of Turkestan alfalfa, S. P. I. No. 991, that lived through the winter successfully. Inasmuch as this same stock of seed suffered quite severely in the present row experiments at Dickinson the records were investigated to learn what caused the difference.

So far as temperature was concerned conditions were certainly more trying in the winter of 1898–99 than during the winter of 1908–9. According to Prof. E. C. Chilcott's records, during December, 1898, there were at Brookings thirteen days with temperatures below zero, the range being from –2° to –22° F. There was no snow during the month. January had fourteen days with minima below zero, the solute minimum temperature for the month being −27° F., which curred on the 30th. The total snowfall for this month was 1.4 ches, which would have made a very light covering in any case, t because of winds was not very evenly distributed. A period of w temperatures began on January 26 and extended until February , culminating on February 9 in −41° F. On the 11th the mercury ain fell to −38° F. Only 2.1 inches of snow fell during February; nce, the plat of Turkestan alfalfa had only such snow protection was held by its own plant covering. Between February 5 and 12 e highest minimum temperature experienced was −25° F., while e highest of the maxima was 5° F. The spring weather was in all spects favorable, there being no alternate thawing and freezing orthy of mention.

The severe temperatures endured by S. P. I. No. 991 at Brookings in ebruary, 1899, as compared with the same strain at Dickinson in nuary, 1909, makes it evident that there must have been some ther difference in weather than temperature between the two winrs to explain the extensive killing in one case and the living over in e other. An investigation of the precipitation record at Brookings ows that during September, 1898, 1.31 inches of rain fell between he 1st and the 15th; that only a little over 1 inch fell in October, all efore the 15th, with snowfall on the 18th. It seems evident from his that the difference in autumn moisture and the consequent aturation of the soil was probably the determining factor at Brookgs in the wintering over of No. 991. That autumn moisture intereres with plants becoming dormant agrees in a way with orchard actices in other sections, especially in irrigated areas. Orchardists esiring to harden their trees and force them into dormancy stop rigating to produce the desired effect.

The experiences of the North Dakota Agricultural Experiment tation at Fargo tend to bear out this hypothesis. In 1901 a plat of urkestan alfalfa was seeded on the station farm. This endured sucssfully the winter of 1901–2, but, according to Professor Shepperd, 'failed to pass the winter of 1902–3 successfully, having been badly interkilled. It was given the most trying conditions by having all f its stem growth mowed close to the ground just before cold weather began in the fall. A second plat of Turkestan seeded in the spring of 1902 which was left with a growth of stems a few inches high killed but little during the same winter." The record of rainfall at Fargo during the autumn of 1902 shows that over 5 inches of rain fell in October. This probably accounts largely for the greater amount of winterkilling in the plat from which no moisture was removed through transpiration than in the one left with some growth. Furthermore, the latter had the advantage of a plant covering to hold the snow.

Still other observations have been made which leave little doubt in the matter of winterkilling due to an excess of autumn moisture.[a] Prof. W. A. Wheeler in a paper presented before the Dry Farming Congress, at Billings, Mont., in October, 1909, called attention to the fact that the winter of 1905–6 resulted very disastrously to the nursery row experiments at the South Dakota substation at Highmore. Professor Wheeler commented especially on a northern-grown strain of common alfalfa which was almost wholly killed out. Only the Grimm alfalfa, acclimatized Turkestan alfalfa, and South Dakota No. 167—the so-called Baltic alfalfa—endured this winter successfully, and there was some killing in the two last named of these strains. The precipitation record for Highmore shows that almost 2 inches of rain fell in October, 1908, while the precipitation for November amounted to 1.29 inches. The alfalfas under experiment that suffered the worst were grown in rows, as at Dickinson; hence, the disastrous effect of this amount of rainfall was no doubt much greater than in thick stands.

This same winter (1905–6) is the only one in recent years which has injured seriously the stands of Grimm alfalfa in Carver County, Minnesota. Farmers have generally believed that the killing which took place that winter was due to the alternate thawing and freezing during February. A careful study of Minnesota winters for a period of years shows that many have had more severe conditions in this respect, hence it did not seem likely that this condition furnished a sufficient explanation. Again, the precipitation records were consulted and it was found that the September rainfall amounted to 4.15 inches, the October rainfall to 2.49 inches, while the precipitation for November which was practically all rain was almost 2½ inches. It was noted that the killing was especially bad in the "draws," or depressions, which furnished drainage to the fields. Even where these "draws" or natural drainage ditches were on sidehills, as shown in Plate IV, figure 2, where water could not remain standing, the killing was severe. From this it seems that the condition was not one of an ice covering, but of saturation.

These examples have been selected to give further emphasis to the importance of autumn moisture. It has frequently been the case in irrigated sections that late irrigation has caused the killing out of alfalfa fields. However, it has generally been believed that the killing occurred only because the winters were open. The results at Brookings after the winter of 1898–99 indicate that open winters preceded by ry autumns, even when the temperatures are very severe, are not to e compared in injuriousness to winters preceded by moist autumns.

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[a] A brief but interesting discussion of the winterkilling of alfalfa under irrigation has been published recently by Prof. Samuel Fortier. See Farmers' Bulletin 373, U. S. Dept. of Agriculture, entitled "Irrigation of Alfalfa," 1909, pp. 41–42.

In the Milk River Valley of Montana ordinary alfalfa maintains its tands from eight to fifteen years, despite the fact that temperatures onsiderably lower than – 40° F. occur rather frequently. Progressive hinning of the stand of course makes it necessary to reseed sooner or ater. This is a region of scant autumn rainfall, which probably ccounts for the success obtained in growing ordinary alfalfa. This ame strain in Minnesota, North and South Dakota, Wisconsin, and many other Northern States succumbs in from two to five years, someimes even sooner, though the temperatures generally are not nearly so ow as those of northern Montana. All of these facts seem to indicate hat moisture in the soil is one of the most important factors in determining whether or not alfalfa will winter over successfully.

DIVERSITY IN ALFALFA.

Alfalfa appears to be quite as diverse physiologically as it is botanically, and in the majority of cases botanical or morphological lines of descent seem to have no correlation with the physiological. That this should be the case is not surprising in a crop where the greatest freedom of interbreeding promoted by special adaptations for making insect visits effective is the rule. As a result of this condition strains that have by natural selection been rendered uniform with reference to physiological characters, such as cold resistance or drought resistance, may contain still the whole range of botanical diversity, so far as this is expressed in the external appearance of the plants.

Strains of Grimm alfalfa, for instance, contain lines of great morphological diversity. Some are prostrate, some upright; some leaf profusely, others very sparingly; some incline to coarse woody stems, others to fine tender ones; some have small leaves, others large; some show only one of a number of flower colors, others are variegated, and so on through the whole range of possible differences. In the experiments thus far conducted none of these diverse elements have shown any observable differences in cold resistance. This suggests the possibility that the hardiness may be due to some histological character common to all the lines of descent.

Investigations of the physiology and histology of cold resistance have not yet produced much definite information, but it does not appear necessary to assume any one character as the basis of hardiness. Some lines may live through severe test conditions from one cause and some from another; in some it may be due to the faculty of becoming dormant at the proper time, in others to the habit of growing from deep-seated crowns, in still others to the power of reestablishing a root system quickly when heaving or freezing had broken off the root.

As our knowledge of individual alfalfa plants becomes more intimate, some true correlations between the morphological and physiological characters may be found. At present we have few data along this line.

The belief has grown up recently that diversity or variegation in flower color is correlated with hardiness, and that drought resistance and cold resistance are also correlated. The evidence of the present investigations has been negative on both of these points. On the field plats the Kansas strain No. 19508, which undoubtedly came from Europe originally, has practically the same range of flower color as the Grimm strains. While one of the latter suffered no winterkilling and the other but little, the Kansas strain killed so badly that only about 20 per cent of a stand remained. The Grimm strains, as we have already seen, differed from one another in hardiness, though not in diversity of flower color. The two strains of commercial sand lucern S. P. I. Nos. 21217 and 21269 are far more variegated in color than any Grimm plants, still they proved less hardy on both the field plats and in the rows and also in experiments elsewhere in the Northwest. They themselves showed considerable difference in hardiness. On the other hand, strains like Wheeler's acclimatized Turkestan (S. Dak. No. 240), which has no variegation, proved hardier than any variety except the Grimm. This indicates that in the strains mentioned, at least, the factors producing cold endurance are independent of variegation or the factors producing it.

Similarly, it has been believed that drought resistance is correlated with hardiness. Some of the best drought-resistant varieties, however, proved in the row experiments to be the very weakest strains from a cold-resistance standpoint. The only dry-land form that showed any cold resistance worthy of comment came from Sextorp, Nebr., where in addition to a lack of sufficient rainfall low temperatures are often experienced.

Ordinary American alfalfa, which probably traces its history back to a single lot of seed taken from Spain to South America several centuries ago, also showed a range of more than 50 per cent in hardiness.

METHODS BY WHICH ALFALFAS BECOME HARDY.

A study of the whole group of alfalfas reveals the fact that the total range in variation in hardiness is much greater than in our common American strains. The best strain in the Dickinson experiment, a Grimm, lost less than 3 per cent, while twelve kinds killed out 100 per cent. Among the latter were four Arabian stocks that winterkilled completely in row and hill tests as far south as Stockton, Kans., ere the winter of 1908–9 was milder than normal. This variation ardiness of the different stocks is correlated positively with an in- inite minimum temperature or complex of climatic conditions of country in which they have long been grown. In other words, tenderest of the alfalfas come from the warmest regions and the dier ones come from the colder regions.

The first method of securing a hardy alfalfa is illustrated in the case Grimm alfalfa, South Dakota Nos. 240 (originally from Turkestan) d 167, and by those strains of ordinary American alfalfa that show re than average hardiness.

The evidence is good and fairly conclusive that the alfalfa which endelin Grimm brought over from Germany in 1857 was neither tter nor worse than the average central European alfalfa. It also ntained many lines, some of which were hardier than others. Mr. imm did not start a nursery and propagate one plant that showed elf superior to the others. He sowed the whole lot of seed and rvested what he could. This was done repeatedly and as the years ssed by nature weeded out the tender lines, while the hardier ones rsisted.

This process no doubt gradually brought about a profound change the stock as a whole. It is, however, not necessary to suppose at the lines which have persisted in the Grimm alfalfa are any different than they were in the original seed brought over fifty years o. They are simply more abundantly represented in the popula- n making up the strain. On the other hand, it may be that the rimm stocks used in our experiments do possess lines hardier than y contained in the foundation stock. These could have arisen adily by mutation, a recombination of characters,[a] or otherwise nce the date of the introduction of the strain. This assumption is t necessary, as all the central European alfalfas that underwent the verest test of the row and hill experiment possessed some hardy es which could be made the basis of further propagation.

Another method may be used, but the ultimate principles involved e the same. As already pointed out, any stock of alfalfa seed, even hen grown in a restricted area for a long time, is made up of a num- er of lines or families which vary both morphologically and physio- gically and which breed more or less true. In our study of hardiness e majority of strains or regional varieties possessed some plants hich lived through the northwestern winter. The plants that lived hrough were representatives of the hardier lines. Now evidently a simple method of securing cold endurance is to select any represent tive hardy plant and increase it. By this method of breeding we a led to the establishment of a pure or nearly pure strain.

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[a] Methods by which recombinations produce a change in cross-fertilized plants are scussed by Prof. W. J. Spillman. See "Application of Some of the Principles of eredity to Plant Breeding," Bulletin 165, Bureau of Plant Industry, U. S. Dept. Agriculture, 1909, pp. 36–43.

The Minnesota Agricultural Experiment Station and Prof. W. Wheeler, of South Dakota, have followed this method, basing th pure strains largely on selected Grimm plants. During the pa season Professor Wheeler produced as much as 200 pounds of se that traces its ancestry to a single plant. This method is also bei followed by Mr. A. C. Dillman, of the Office of Alkali and Droug Resistant Plant Breeding Investigations, in his work at Bell fourche, S. Dak.

In this method the singling out of the representative plant is th important thing. It naturally presupposes some antecedent metho of getting rid of the weaklings and hence applies not so much to th establishment of a hardy race as to the isolation of a pure or unifor race from a mixture of predetermined hardiness. The advantag and disadvantages of this method are little known. Observatio on other crops indicate that there is considerable danger in a to narrow restriction of lines of descent.[a]

The length of time required to produce from a mixed stock by un conscious mass selection[b] an approximately pure race, so far as col resistance is concerned, is uncertain. It will evidently depen almost wholly on two factors, namely, the abundance of hardy in dividuals in the original stock and the frequency with which te winters occur.

South Dakota No. 240 (see pp. 51–55) is an example of the estab lishment of a very hardy and nearly pure strain from a mixed strai having a lesser degree of hardiness. The new hardy strain was devel oped immediately, without the necessity of intercrossing or long continued selection. The experience with this strain and observatio on others indicate that the time required need not be long. Th original seeding in the case of No. 240 was made in 1899; the see used in the experiment was harvested in 1906. A study of the record for Highmore, S. Dak., and neighboring points shows that test weath conditions prevailed several times during the interim.[c]

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[a] Our knowledge of the amount of cross-pollination that takes place when all plants are left exposed is very deficient. If we wish to select a line and propagate pure, the prevention of cross-pollination is necessary. If the plant selected is an cross with regard to any character, then it is obvious that the selection and self-pol lination of several individual plants may be necessary in the next generation before really pure strain is obtained.

[b] Cook, O. F. The Superiority of Line Breeding over Narrow Breeding. Bulleti 146, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 28–29.

[c] The following minimum temperatures at Highmore, S. Dak., indicate the natur of the test that alfalfa endures in this locality: 1904, −27° F.; 1905, −36° F.; 190 −31° F.; 1907, −27° F.

The seed production of No. 240 has been uniformly poor. Most stocks of Turkestan alfalfa share in this weakness. In some years he plats appear not to have been cut at all; in 1904 only the first crop was removed. In consequence of this, the surviving plants undoubtedly produced seed which was not harvested, but fell on the ground, thus bringing about natural reseeding. In this case seven years of unconscious mass selection toward cold resistance resulted n an unusually hardy strain. The Grimm variety is the product of fifty years of similar selection in the Northwest.

The term "selective acclimatization" may be applied to this process of change whereby hardy lines or races in a crop plant are accenuated in later generations by the elimination from year to year of unfit lines. The versatility of a race produced in this way in meetng new conditions in other areas than the one in which it was developed will probably hinge largely on the range of selective factors to which it has been subjected in its previous history.

Hybridization between alfalfa and its wild relatives has been suggested as an immediate method of securing hardiness.[a] Its use, however, would not dispose of the necessity of selection both before and after the making of the crosses. Antecedent selection will be equired for determining the hardiness of the chosen parents of both the wild and cultivated stocks, while the subsequent selection will be essential for eliminating the nonhardy by-products of crossing and isolating the lines of high forage and seed value.

CONCLUSION.

The investigations that form the basis of the present paper have been under way at Dickinson, N. Dak., for nearly four years. At other places in the Northwest they have continued a year longer. The observations recorded show that the employment of good tillage, the use of a suitable strain of seed, and the character of the winter weather are the controlling factors in successful alfalfa production in the Northwest when soils of average fertility are used.

With reference to tillage it may be said that the previous cropping and treatment of the soil and its thorough preparation are of primary importance. Inoculation, irrespective of the manner in which it is secured, determines success or failure, even though all other conditions are satisfied.

It was found that by varying the time of cutting in order to leave considerable growth on the field in the autumn, even the strains of inferior hardiness endured, though the conditions were severe. This result appeared to be due to the exhaustion of moisture from the soil in the autumn and to a plant covering which held a protective blanket of snow over the alfalfa crowns during severe weather. Thinness of stand resulted in a high percentage of winterkilling in all except the hardiest varieties. Farmers who are unable to secure sufficient seed of hardy strains for acreage plantings may find it profitable to use less hardy strains, planning to leave the late summer and early fall growth standing to hold the snow.

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[a] For an extended discussion of this point of view, see Westgate, J. M., "Variegated Alfalfa," Bulletin 169, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910.

Thoroughness in preparing the soil promotes inoculation, which is essential to satisfactory yields. Lack of attention to this point has led in thousands of cases to the plowing up of alfalfa stands in the Northwest that would otherwise have been successful. Inoculation is just as necessary for hardy as for nonhardy strains of seed.

Present experiments show that undoubtedly the most important cause of failure in actual practice has been the use of seed from regions that in the nature of things can not produce adapted seed. In practically all of the present alfalfa-growing areas of the United States, ordinary American alfalfa and commercial importations of seed from abroad have proved to be entirely satisfactory or else so easily adaptable to conditions as to become satisfactory after one or two generations of seed have been produced. This is particularly true where alfalfa is grown under irrigation. Even as far north as the Yellowstone and Milk River valleys of Montana ordinary Utah seed has given satisfactory results, except in unusual years. In the more humid parts of the cold North and Northwest this has not proved the case. After a severe winter in these sections fields of nonhardy forms of alfalfa show only the dry crowns of dead plants, with here and there a growing plant. The profusion of the latter depends wholly upon the degree of winter resistance of the particular strain used, that is, upon the percentage of cold-resistant individuals included in its population.

Our knowledge is still meager as to what quality or qualities produce hardiness in different races of alfalfa. The importance of ability to become dormant in spite of weather calculated to force continued growth has been pointed out. At least two other characteristics of the plants themselves have been observed that are believed to be of importance. The Mongolian alfalfa which proved to be the hardiest under the severe test at Dickinson of any of the newly imported strains was found both there and at Stockton, Kans., to have crowns more deeply set in the soil than other varieties. It seems likely that this adaptation, if it may be called an adaptation, is of importance in giving the tenderest part of the plant the needed protection.

Another condition has been noted, especially in Grimm alfalfa. On taking up the crowns in old stands it has been observed that at some previous time the taproot has been completely broken off from to 8 inches below the surface.[a] Living plants in such cases have developed new roots laterally to take the place of the broken ones. This condition has suggested the possibility that the long endurance of stands of the Grimm strain may be due in some measure to a capacity for putting out new roots and reestablishing itself after the taproot has been broken. The data collected on this point do not yet justify anything like positive statements, but it is mentioned in this connection to stimulate growers and breeders to make note of similar conditions.

With reference to weather conditions, which because of their importance have been discussed rather fully in the present paper, the following appeared to be the most destructive to alfalfa stands under the conditions studied:

(1) A lack of sufficient snowfall or the exposure of plants, due to drifting. The latter condition can often be remedied by making the last cutting of hay early enough so that the field will have 8 or 10 inches of plant growth to bind the snow.

(2) Successive thawing and freezing, which may kill the plants outright by rupturing their tissues or kill them indirectly by heaving the soil, thus breaking the main roots and stripping off the lateral roots. The crown of a plant killed in this way can be drawn from the ground without effort, and in the spring it usually dries out before it can reestablish itself.

(3) An excess of moisture in the autumn which by preventing the plants from hardening up their tissues results in their being in a more or less tender and succulent condition when winter weather sets in. Alternate thawing and freezing are especially deadly when a wet autumn or a late irrigation leaves a high percentage of moisture in the soil.

Dry winters have been supposed to be highly injurious to alfalfa, but the writers' observations indicate that it is only the dry winters which are preceded by moist autumns that do the greatest injury. A dry fall furnishes more favorable conditions for wintering over by producing more perfect dormancy. In the well-recognized alfalfa-growing areas of the United States winterkilling has never occasioned excessive losses.

Observations elsewhere than at Dickinson have shown at least two other important external conditions that conduce to winterkilling, namely, sleet or a coat of ice which is usually an accompaniment of alternate thawing and freezing, and severe pasturing, whether by cattle, sheep, or hogs, especially if it is carried late into the autumn. In the case of ice formation it seems probable that the plants are injured both by a rupture of the tissues and through being deprived of the necessary aeration.

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[a] Mr. T. H. Kearney calls attention to the fact that ordinary alfalfa in Arizona does this when the taproot has been destroyed by Ozonium. This disease has not been found in Carver County, Minnesota.

No doubt many other factors in addition to those discussed in this bulletin are concerned in the rapid depreciation of alfalfa stands in cold climates. It is hoped that the present investigations may contribute to a fuller knowledge of the subject and assist in the establishment of an alfalfa industry in the Northwest comparable to that which has grown up farther west and in the Southwest within the past fifty years.

PLATES.

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DESCRIPTION OF PLATES.

Plate I. (*Frontispiece.*) Fig. 1.—Experimental plats of alfalfa in hills and drill r at Dickinson, N. Dak., on October 1, 1908. Each row was sown to a diffe strain in the spring of 1908, 68 kinds in all, and on the date the photograph for this illustration was taken practically every one had a full stand. Fig. 2.— same experimental plats at Dickinson, N. Dak., on June 10, 1909, showin great diversity in the winter resistance of alfalfa from different parts of the w The statistics of winterkilling for the section in the immediate foregro rows 35 to 68, counting from right to left along the white stakes in the midd the picture, are shown in the second part of Table XIII. Those for rows 1 t comprising the section between the first and second complete lines of stakes, presented in the first half of Table XIII.

Plate II. Fig 1.—Experimental plats showing the importance of a snow coveri The small patch of red clover in the foreground stands in the meager shelter of old back furrow. This furrow, which is only slightly higher than the soil aro it, held a few inches of drifting snow over the plants and preserved them f injury, while the remainder of the plat, which is only a few hundred feet from alfalfa nursery, killed out completely. Fig. 2.—Experimental plats at Stock Kans., showing the winterkilling of North African and Arabian alfalfa in the mil winter of 1908-9. The middle row is Kebilli Oasis alfalfa, No. 12846, secured b Mr. T. H. Kearney from Tunis. At Dickinson, N. Dak., this strain killed o 100 per cent. (See row 20, Table XIII.) The row at the right of this, showing few plants, is from Tripoli. Two rows to the right of the Tripolitan strain and the left of the Tunisian are Arabian alfalfa, the tenderest variety known. Not living plant at Stockton remained in any of the Arabian rows in the sprin These rows are identical with Nos. 6, 7, 8, and 9, Table XIII, Dickins experiments.

Plate III. Fig. 1.—Experimental plats showing seven rows of European alfal after the winter of 1908-9 at Dickinson, N. Dak. The four rows to the left of t arrow nearest the middle of the picture, Table XIII, rows 57 to 60, inclusive. the so-called commercial or false sand lucern from France and Germany. Row is Italian alfalfa and row 62 Provence alfalfa grown in Germany. Row 63, imm diately to the right of the arrow nearest the margin, is another sample of co mercial sand lucern. The two rows to the right of the middle arrow, rows 56 55, Table XIII, are Utah dry-land alfalfa. Next is South Dakota No. 167, r the so-called Baltic alfalfa, while between this and the two rows of Grimm at the right, is a row of Brott's Nebraska dry-land alfalfa. Fig. 2.—Experi plats showing three rows of Mongolian, the hardiest newly imported alfalfa in in the experiment, Dickinson, N. Dak., August, 1909. (See rows 2, 3, Table XIII.)

Plate IV. Fig. 1.—Experimental plats showing the winterkilling of North Am alfalfa and some other strains at Dickinson, N. Dak. Photographed Jun 1909. The row indicated by the arrow, row 47, Table XIII, is Colorado a which was included in the field, plat, and row experiments. In order, the r the left of the arrow are as follows: No. 48, Kansas; 49, Chinook, Mont.; 50, water, Nebr.; 51, Minnesota Grimm; 52, North Dakota Grimm. To the left arrow are the following: No. 46, first quality commercial, of European with variegated flower color; 45 and 44, Mexico; 43 and 42, Canada; 41, Bi Mont.; 40, Wheeler's acclimatized Turkestan. Fig. 2.—A field of Grimm in Carver County, Minnesota, showing the nature of the severe winterkilli 1905-6. Although this field is located on a sidehill, so that no water could r standing on it, considerable winterkilling took place in the "draws" or natu drainage courses of the field where the soil had become oversaturated by autu moisture. Photographed in September, 1909.

PLATE II.

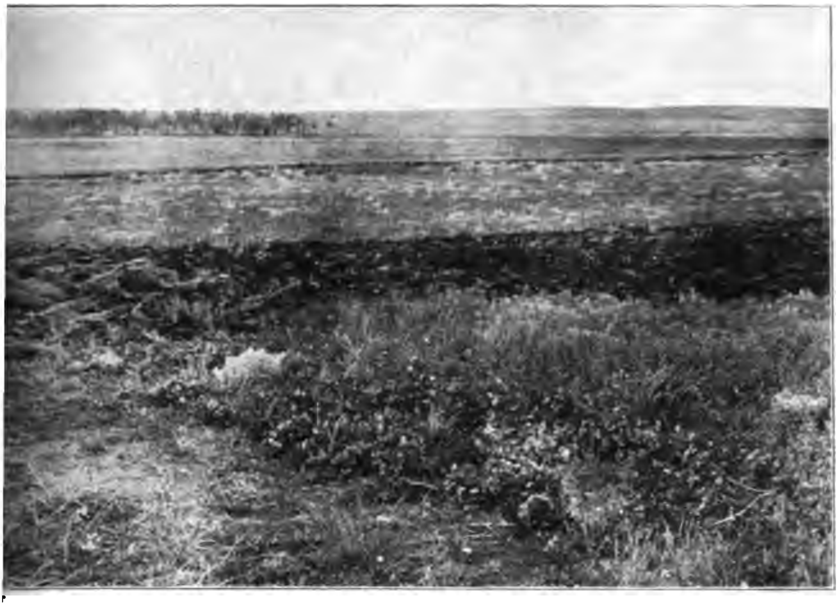

FIG. 1.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., JUNE 12, 1909, SHOWING THE IMPORTANCE OF A SNOW COVERING.

The patch of red clover in the foreground was preserved by a light covering; the remainder of the field was killed out.

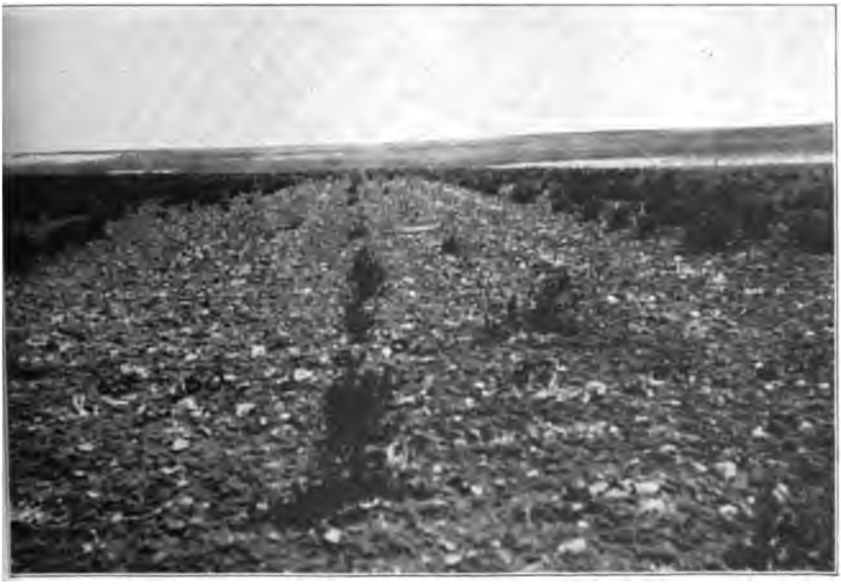

FIG. 2.—EXPERIMENTAL PLATS AT STOCKTON, KANS., SHOWING THE WINTERKILLING OF NORTH AFRICAN AND ARABIAN ALFALFAS DURING THE MILD WINTER OF 1908-9.

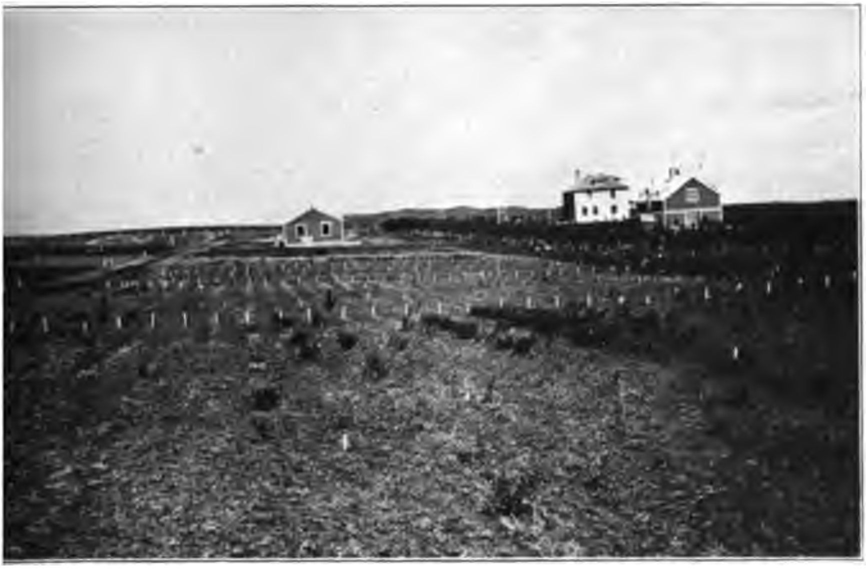

FIG. 1.—EXPERIMENTAL PLATS OF EUROPEAN ALFALFAS AFTER THE WINTER OF 1908-9 AT DICKINSON, N. DAK.

The seven rows between the arrows (Nos. 57 to 63, counting from right to left) are from Europe.

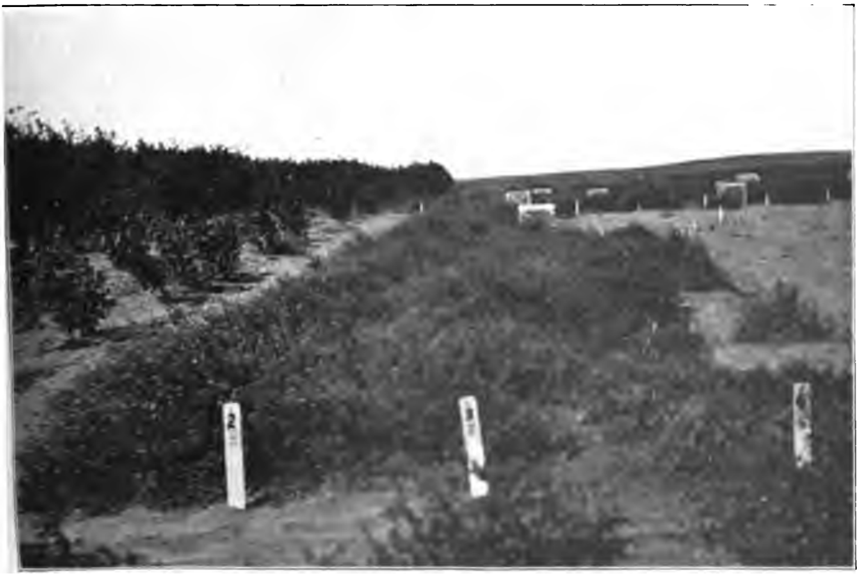

FIG. 2.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., AUGUST, 1909, SHOWING THREE ROWS OF MONGOLIAN ALFALFA, THE HARDIEST FOREIGN-GROWN STRAIN.

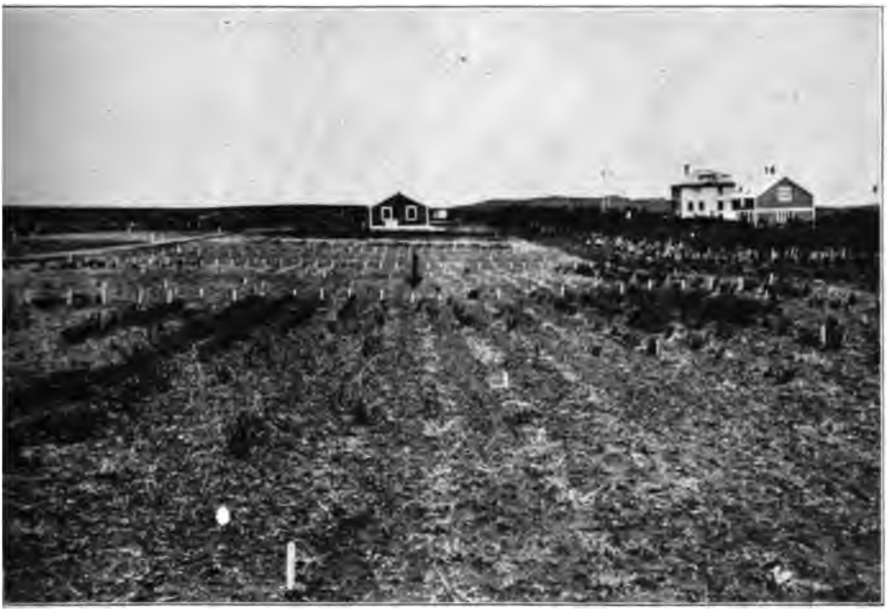

FIG. 1.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., SHOWING THE WINTERKILLING OF NORTH AMERICAN STRAINS OF ALFALFA.

The rows are numbered from right to left, the arrow indicating No. 47.

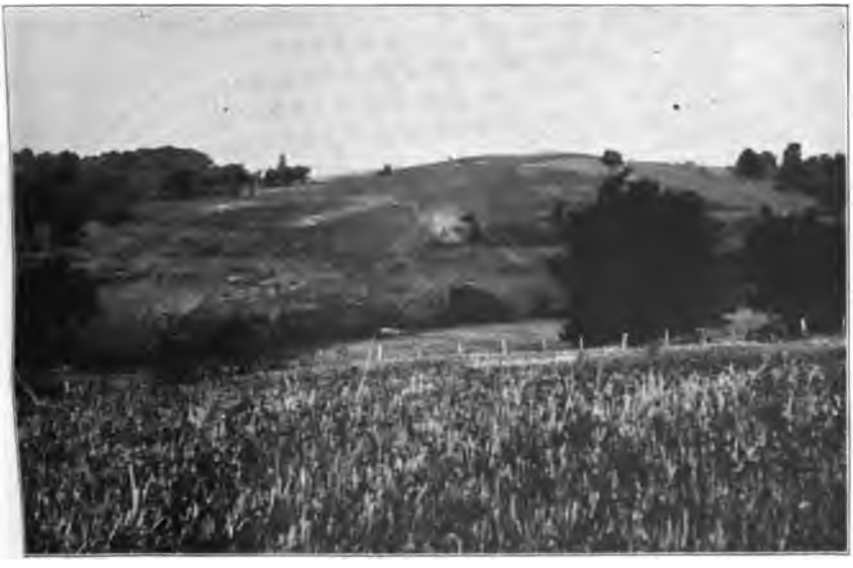

FIG. 2.—A FIELD OF GRIMM ALFALFA IN CARVER COUNTY, MINNESOTA, SHOWING THE WINTERKILLING IN 1905-6 IN THE "DRAWS" OR NATURAL DRAINAGE COURSES OF THE FIELD.

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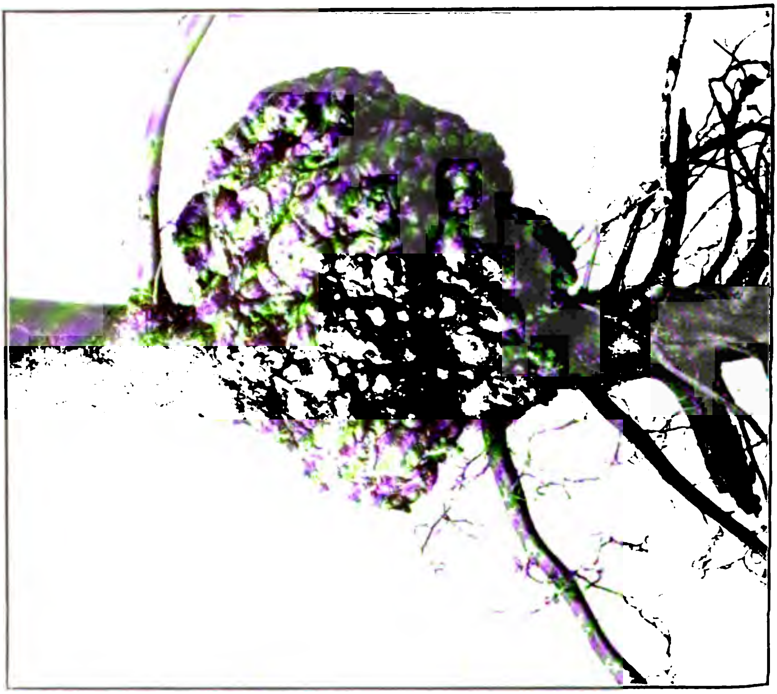

FIG. 1.—HARD FORM OF CROWN-GALL OF THE APPLE.

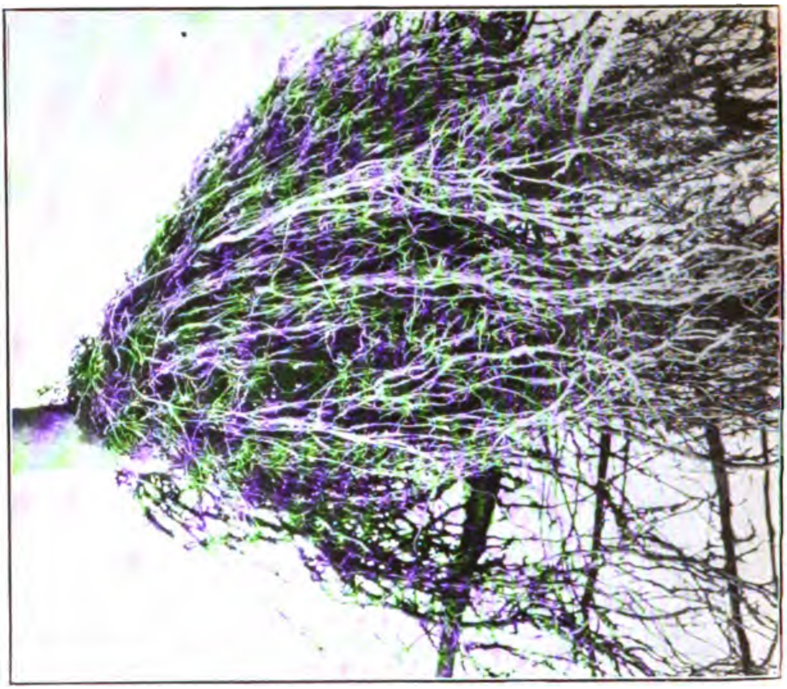

FIG. 2.—WOOLLY-KNOT FORM OF HAIRY-ROOT OF THE APPLE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 186.

B. T. GALLOWAY, *Chief of Bureau.*

FIELD STUDIES OF THE CROWN-GALL AND HAIRY-ROOT OF THE APPLE TREE.

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BY

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PATHOLOGIST, FRUIT-DISEASE INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 15, 1910.

Sir: I have the honor to transmit herewith a manuscript entitled Field Studies of Crown-Gall and Hairy-Root of the Apple Tree," y Dr. George G. Hedgcock, at present Pathologist in Investigations n Forest Pathology.

This paper embodies the results of several years of investigation nd experiment and covers the distribution of crown-gall and hairy-oot, a description of their different forms, their probable relations, nd their development; the effect of the diseases upon apple trees; he susceptibility of varieties; communicability in the nursery and rchard; and prevention and cure. The paper marks the comple-ion of Doctor Hedgcock's work on this subject. The field study f these diseases will be continued by the Office of Fruit-Disease Investigations.

Studies of the etiology and interrelations of crown-gall have been made by Messrs. Smith and Townsend and by Miss Brown, of the Bureau of Plant Industry, and are still in progress.

I respectfully recommend that this manuscript be published as Bulletin No. 186 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—580.

FIELD STUDIES OF THE CROWN-GALL AND HAIRY-ROOT OF THE APPLE TREE.

INTRODUCTION.

Growers of fruit trees have noted for many years a diseased condition of apple trees which usually manifests itself on young trees in the formation of galls and of clustered or fasciated roots at or near the surface of the ground, and on older trees in the form of knots or tumors occurring on the branches. These forms of disease have been variously designated as "galls," "crown-gall," "crown-knot," "hairy-root," "woolly-knot," "woolly-root," "broom-root," "root knots," "root galls," and "tumors."

In recent years these forms of the disease have been brought prominently before the public by a number of investigators. As a result of the consequent agitation, following statements alleging their dangerous nature, many States have enacted stringent laws for prevention and control. Although such laws, as a rule, should be enacted as a matter of precaution, in this case they have entailed great hardship and loss to nurserymen. An estimate of this loss, based upon reports received from leading wholesale nurserymen in various parts of the country, places the amount at not less than half a million dollars annually. The actual loss to orchardists is uncertain. In fact, data from exact and careful orchard experiments have not hitherto been available.

A very unsatisfactory condition has arisen from the widely divergent opinions of observers relative to the communicability of crown-gall and to its effect. State laws upon the control of these forms of disease vary as much as the opinions of those who have made observations upon their effect. Consequently, there has arisen an urgent demand from nurserymen and horticulturists for more exact data on their nature. In response to this demand, a series of studies and experiments, embracing the greater portion of the United States, has been conducted by the writer for a continuous period of seven years. This investigation has included the forms of disease ordinarily known as "crown-gall" and "hairy-root" attacking many kinds of trees, vines, and shrubs, embracing a study of the cause, communicability, effect, and extent of the various forms of disease.

This bulletin embodies the results of that portion of the investigation which relates to apple[a] trees. An endeavor is made to set forth clearly the nature of the disease and its effect upon trees in the nursery and the orchard, as well as to recommend methods for its control in the orchard. Of no less importance is the information for nurserymen resulting from a large number of experiments in nursery practice. Methods are given whereby loss caused by some forms of crown-gall and hairy-root may be either lessened or almost completely eliminated without greatly increasing the cost of growing trees in the nursery. Finally, it is shown by actual experiment that in the case of the milder and usual forms of the disease little or no injury is appreciable in young orchards. More intense forms, however, may be injurious, but in an orchard these rarely develop from the milder forms. No proof has been found that any of the forms are beneficial, as in case of the root tubercles of legumes.

The writer has briefly described in this and in previous publications a number of forms of crown-gall and hairy-root. There remain some points of doubt to be cleared up by other investigators, since this publication concludes the writer's work on this subject. In the discussion which follows, for reasons given later and in order not to confuse the reader, all forms of crown-gall and hairy-root will be considered as forms of the same disease.

The results of many experiments are given, some of which were conducted in Missouri, Illinois, Iowa, Nebraska, Kansas, and Arkansas, and others in the District of Columbia and Virginia. It is necessary, for brevity, to say in the beginning that all experiments were prepared and conducted under the personal supervision of the writer and that all portions of each experiment were equally well prepared and cared for under similar conditions. Where such is not the case mention is made of the fact.

In the index to literature, on pages 93 to 96 of this bulletin, are cited all of the principal publications on apple crown-gall and hairy-root published in the United States, as well as many of those in other countries. A number of American and foreign publications on the subject of crown-gall deal with the disease on other hosts than the apple, and these have not been cited.

Prior to July, 1907, the work of investigation was conducted in the Mississippi Valley Laboratory of the Department of Agriculture at St. Louis, Mo., under the supervision of Dr. Hermann von Schrenk.

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[a] Owing to the confusion in the nomenclature of many of the common varieties of apples, all of the names used in this bulletin are in accordance with the "Nomenclature of the Apple," by W. H. Ragan, Bulletin 56, Bureau of Plant Industry, issued January 25, 1905.

HISTORICAL NOTES ON CROWN-GALL AND HAIRY-ROOT.

The forms of the disease originally known as "crown-gall," consisting of fleshy outgrowths on the roots of fruit trees, have been known by nurserymen to occur in the United States for nearly half a century, although the first published mention of them is much later. In fact, about all the literature on the subject dates since 1890. No one can be certain as to the time of the first appearance of the disease in this country. In the opinion of the writer it was introduced with plants from Europe. The Europeans have known the disease, or a similar one, for many years. According to Sorauer (57 [a]) the Wurzelkropf, which may be considered the same disease, occurs on the apple and the pear in Germany.

Owing to its wide geographic distribution, crown-gall has attracted the attention of a number of investigators in this country. Bailey (5) and Stewart (62) in New York; Clinton (8) in Connecticut; Selby (49) in Ohio; Taft (65) in Michigan; Woodworth (79), Wickson (77), and W. E. Smith (56) in California; Toumey (68) in Arizona; Forbes (10) in Illinois; Alwood (1) and Phillips (40) in Virginia; and E. F. Smith (53), E. F. Smith and Townsend (54), von Schrenk (71), and Hedgcock (19) of this Department have published articles concerning the crown-gall forms of the disease. Others are cited later in this bulletin.

The forms of the disease known as hairy-root have been observed by some of the older nurserymen ever since they have grown apple trees, dating back nearly fifty years. Attention was first called to the disease in this country by Stewart, Rolfs, and Hall (64). In 1900 they described the simple form of hairy-root on apple seedlings in New York, giving it the name "hairy-root," which had already been applied to the disease by nurserymen. This form and three other forms of the disease have since been recognized and described by the writer (21).

In Europe at least two forms of the disease have been described by German investigators. That known in Germany as "Wurzelkropf" is apparently identical with crown-gall. Frank (14) and Sorauer (58) have described this disease on the apple and the pear. A second form of the disease in Germany, which is apparently identical with the aerial form of hairy-root, is called "Kropfmaser" by Frank (14) and Sorauer (61). Kissa (30) describes this disease on *Pirus malus sinensis*. Julie Jaeger (28) describes the same disease on the limbs of apple trees. Wakker (74) describes a similar disease on species of Ribes in Holland.

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[a] The numbers in parentheses used in this paper refer to the index to literature on pp. 93–96.

DISTRIBUTION OF THE DISEASE AND RELATED FORMS.

GEOGRAPHICAL DISTRIBUTION.

The hard and soft forms of crown-gall on the apple tree and on various other plants have either been observed by the writer or reported to him by others in practically every State in the Union. The writer has found both forms of the disease on apple trees in every locality where nurseries were inspected by him, and in many where no nurseries were located. The disease, in both forms, is most abundant in the more southern States of the apple-growing belt, from Virginia to Texas. The writer collected data in 31 States and Territories and received reports of occurrence from correspondents in all of the others except Nevada.

In Europe, as previously mentioned, crown-gall or a similar disease (Wurzelkropf) occurs on apple and pear trees in Germany. The writer finds it common on apple seedlings imported direct from Holland and France. W. S. Blair, in a letter, reports its occurrence in Ontario, Canada, on apple trees.

The forms of the disease known as hairy-root have been found as widely disseminated as crown-gall on apple trees in nurseries and orchards in the United States. In orchards hairy-root is more common than crown-gall.

In Europe the aerial form of hairy-root or a similar form (Kropfmaser) occurs on apple trees in Germany (60). W. S. Blair, by letter, reports the occurrence of hairy-root on the roots of apple trees in Ontario. Hairy-root of the simple and of the woolly-knot form has been found by the writer on trees imported into the United States from New Zealand.

DISTRIBUTION IN NURSERIES.

In seedling nurseries apple trees are grown for one season from seed, then dug and used for propagation in budding and root grafting. The writer inspected the stock at the time of digging in a number of the largest seedling nurseries in Kansas, Nebraska, Iowa, and Missouri. In one lot of 300,000 apple seedlings examined, sorted, and and counted under his supervision, less than one-half of 1 per cent was diseased with crown-gall, almost entirely of the soft form, and about 1 per cent with hairy-root, chiefly of the simple form. This percentage holds good for all of the nurseries examined.

In nurseries where trees are propagated by budding and root grafting, as compared with seedling nurseries, there is a much greater percentage of disease. On trees grown from root grafts there is more disease than on those propagated on seedlings by budding. The relative percentage of disease of each form found on budded and grafted trees in nursery experiments is shown on pages 18 and 19.

DESCRIPTION OF THE DIFFERENT FORMS OF THE DISEASE ON APPLE TREES.

FORMS OF CROWN-GALL.

The term "crown-gall" as used in this bulletin applies to the fleshy outgrowths, or galls, occurring rarely on the stems and frequently on the crown and the roots of apple trees. It is applied only to those galls that are not accompanied by an excessive formation of either roots or incipient roots and are not caused by insects. Two forms have been recognized by the writer—the soft and the hard (19).

Soft crown-gall.—The term "soft crown-gall" has been applied to the form most frequently found on young seedling, grafted, and budded apple trees (Pl. II, figs. 1 and 2). These galls consist at first of a soft, succulent growth of young cells thrust out from the cambial layer of roots or shoots. They commonly originate in wounds and their initial growth is quite similar to that of an enlarged callus (Pl. VIII, fig. 2), which they resemble in form, color, and structure. The surface of the galls, owing to an unequal growth of the elements in the tissues, soon becomes coarsely convoluted. Curled and distorted masses of wood cells and vessels are gradually formed throughout the softer tissues, often causing the galls to become hard and woody in the interior. At first the color of the surface is white, but later it either changes to the color of the adjacent healthy tissues or becomes brown or black from the decay of the surface cells, which at no time are protected by an epidermis.

In size these galls usually vary from that of a pea to that of a man's fist, but in exceptional cases they may grow to the size of a man's head. They do not develop roots from their surface, and under natural conditions in the nursery they generally decay at the end of the growing season. In general appearance and structure they resemble the crown galls of the almond, apricot, blackberry, cherry, chestnut, grape, peach, pear, plum, raspberry, rose, and walnut, to which they are related (22).

Hard crown-gall.—The term "hard crown-gall" has been applied to the form occurring more frequently on older trees in nurseries and orchards (Pl. II, figs. 3, 4, and 5). The earlier growth of these hard galls is similar to that of soft crown galls, but later they become covered with bark and develop a woody interior. They finally have a texture intermediate between that of healthy wood and that of soft crown galls. Roots often spring from their tissues and they thus develop into a form of hairy-root (see p. 57). Unlike the soft galls, they do not decay, but continue their growth the following season. The hard galls finally attain the same size as the soft galls, but are much slower in their development. They usually have a more finely convoluted surface and are of the same color as the adjacent healthy tissues. During each period of new growth the bark of the hard galls is usually ruptured, only to be re-formed at the close of the growing season.

FORMS OF HAIRY-ROOT.

The term "hairy-root" as used in this bulletin is a general term applying to four closely related forms of the disease occurring on shoots and roots of apple trees. In these there is an increased and abnormal production of either roots or incipient roots. Four forms have been recognized: The simple, the woolly-knot, the broom-root, and the aerial.

Simple form.—The term "simple hairy-root" has been applied to the form of hairy-root originally described by Stewart, Rolfs, and Hall (64) (Pl. III, fig. 1). This form is the common one on apple seedlings, but occurs less frequently on grafted and budded apple trees in the nursery and the orchard. It consists of numerous small roots growing out at nearly right angles, either singly or in tufts, from an older root or stem (Pl. VI, figs. 2, 3, and 4). This root formation takes place from adventitious buds in the cambial layer, either directly from a root or stem or from swellings thereon. Such roots from the first are more succulent than normal ones. The cells of the parenchyma are hypertrophied and the formation of wood cells is retarded. On exposure to air such roots dry up and become hair-like in appearance.

Woolly-knot form.—A second form, which has been called "woolly-knot," is infrequent on young apple seedlings, but common on older seedlings and on grafted and budded trees in nurseries and orchards. This form originates as follows: A smooth, irregular swelling develops, usually in a larger root near the surface of the soil. This projects at first half an inch or so from the surface of the root. Meanwhile, in the interior of the swelling an incipient root formation takes place. In a few months this usually develops to such an extent that it breaks through the epidermis, producing a warty knot. Under favorable growing conditions, during either the same or succeeding years, there is thrown out from each root center on the surface of the knot a rapid-growing, succulent root, which resembles in development and structure those of the simple form. Many roots usually develop from a single knot. These are often fasciated, and through intricate branching develop into a great mass of fine roots (Pl. I, fig. 2). This form may develop from hard crown-galls. (See p. 57.)

Broom-root form.—A third form of hairy-root occurs frequently on budded and grafted trees in nurseries in States bordering on the Missouri River. It consists of a broom-like formation of fine roots, occurring usually at the end of a side root which otherwise appears healthy (Pl. III, fig. 2). Frequently a broom-root springs from a root which has its origin in a hard crown-gall. Broom-roots resemble those of the woolly-knot in structure, and they develop in much the same way, except that they do not originate directly in swellings, but develop by the excessive branching of root ends. They usually grow upward from their point of origin toward the surface of the soil, in contrast with normal fibrous roots, which grow more nearly parallel to the surface.

Aerial form.—A fourth form of hairy-root, which also has been called "stem tumors" (22), occurs on the trunks and limbs of apple trees, more commonly on older trees in orchards. This form consists at first of smooth, fleshy swellings (Pl. IV, figs. 1, 2, and 3) in which the cambial layer is much thickened. These swellings are more or less rounded, but are often irregular in outline, vary in width from half an inch to 2 or 3 inches, and project from a half inch to an inch beyond the surface of the tree. They develop, internally, incipient adventitious roots, which as the disease progresses break forth, throwing off the outer bark and forming a warty knot (Pl. V, fig. 1). Cuttings containing the disease in its earlier stages readily throw out roots when placed in moist sand or soil in the springtime, developing directly into the woolly-knot form of the disease (Pl. V, fig. 2). On orchard trees as the knot grows older the incipient roots in the center of the knot die, and in some cases new ones are formed in the adjacent healthy tissues, increasing the diameter of the knots but not their projection.

RELATIONS OF THE FORMS OF THE DISEASE TO EACH OTHER.

RELATION OF SOFT CROWN-GALL TO HARD CROWN-GALL.

The work of Smith and Townsend (54) in discovering and demonstrating that *Bacterium tumefaciens* is the cause of the crown-galls of the Paris daisy, the peach, etc., and the work of Townsend with the same or a similar organism from the galls and hairy-root of apple trees indicate that all of the forms of the disease may be caused by the same species of bacterium or some of its forms.[a]

Since the soft and the hard forms of crown-gall are alike in their initial development and since the latter may develop from the former, the two thus differing only in the final form and in duration, it follows that they both may be due to the same cause. It may be that in the case of the hard form the apple tree partially resists the organism causing the disease by healing over the surface of the galls and confining the disease to limited areas, and the soft form may be a more virulent type of the disease.

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[a] See also Smith, Erwin F., Science, n. s., vol. 30, no. 763, August 13, 1909, p. 223.

RELATION OF HAIRY-ROOT TO CROWN-GALL.

Smith, Townsend, and Brown have isolated from hairy-root a bacterium with which they have reproduced the disease on the sugar beet and on the apple. It has not yet been proved that the hairy-root forms of disease may be produced by inoculation of apple trees with *Bacterium tumefaciens*, unless the two organisms Smith, Townsend, and Brown have isolated are identical, but the production of these forms is not morphologically impossible. In the orchard experiments described on pages 38 and 57 it was noted that a considerable number of the trees diseased with hard crown-gall developed hairy-root from the galls.

RELATIONS OF THE FORMS OF HAIRY-ROOT TO EACH OTHER.

The forms of hairy-root are closely related to each other, the essential feature of each consisting of an excessive development of roots, evidently the result of the same sort of stimulus acting upon dormant root centers or buds in the twigs and the trunk of the tree in the case of the aerial form, upon root buds on the main roots in the case of the simple and woolly-knot forms, and upon the side roots in the case of the broom-root form. The woolly-knot form is directly related to the hard form of crown-gall (see p. 20).

European investigators of these forms of disease have always considered the crown-gall (Wurzelkropf, tuberculosis) a different disease from the aerial tumors or the aerial form of hairy-root (Kropfmaser, broussin). As the identity is not completely established, these forms will be treated separately in the experimental data recorded, and all data will be given under the separate forms as hairy-root and crown-gall.

DEVELOPMENT OF THE FORMS OF THE DISEASE.

NO DEVELOPMENT OF THE DISEASE ON SEEDLINGS WITHOUT WOUNDS.

Greenhouse experiments with uninjured seedlings.—In experiments conducted in pots and beds in the greenhouse with uninjured seedlings grown directly from seed (see p. 77), 102 apple seedlings kept free from wounds remained healthy, showing no traces of crown-gall or hairy-root. Of 48 apple seedlings grown under similar conditions, except that the surface layers of soil were mixed with finely chopped pieces of living hard and soft apple galls after the seed had germinated, none became diseased.

Greenhouse experiments with wounded seedlings.—In connection with the experiments mentioned in the preceding paragraph, 98 apple seedlings were grown under the same conditions as the first lot, without soil inoculation. When they were 2 months old each was wounded on the root just below the surface of the soil with a sterile knife. In each case the cut extended upward and through the cambial layer. The blade of the knife was sterilized in a 1-to-1,000 solution of mercuric chlorid before each cut was made. Four seedlings became diseased with small, hard galls, which formed from outgrowths from the cambial layer on the upper edge of the wound. All other wounds healed normally. No formation of hairy-root occurred.

Nursery experiments with young seedlings.—In the nursery it is quite impossible to grow seedlings entirely free from injuries. To ascertain to what extent wounds favor the development of crown-gall and hairy-root, 100 consecutive trees in a nursery row were wounded by a knife cut in the cambial layer, just below the surface of the soil. These trees were about 2 months old when wounded. For a control, the same number of consecutive trees in an adjacent row were selected, in which no wounds were made. At the end of the growing season the trees in both rows were dug. Of the wounded trees, 3 died. Of the remaining wounded trees, 8 were diseased with soft crown-gall, 2 with the simple form of hairy-root, and 2 with the woolly-knot form. Of the control trees, 1 was diseased with soft crown-gall and 2 with the simple form of hairy-root. Thus, four times as many wounded as unwounded trees became diseased.

The percentage of diseased trees in apple-seedling nurseries is usually small. In exceptional cases only is it considerable, no doubt due to injuries received by the young trees during the first two or three months of their growth. This is certainly true in the case of the development of crown-gall, and may apply also in that of hairy-root.

In order to ascertain the relation of wounds to the various forms of crown-gall and hairy-root, 300 diseased yearling apple seedlings were selected, as follows: 100 with soft crown-gall, 50 with hard crown-gall, 100 with the simple form of hairy-root, and 50 with the woolly-knot form of hairy-root. These were dissected to ascertain the presence of wounds in the roots at the time that the disease attacked the seedlings. Such injuries are indicated by the presence of a small discolored rift, showing a break in the tissues near the heart of the tree beneath the outgrowth of the diseased portion. Certain indications of wounds were found under 90 of the soft galls, 47 of the hard galls, and 22 of the woolly-knots. In the case of most of the trees diseased with simple hairy-root, there were discolored areas which were not considered rifts or breaks in the tissues. On the whole, there was decided proof that the first three forms just named are quite closely connected with injuries to the young roots.

Nursery experiments with older seedlings.—In a field experiment at Louisiana, Mo., 350 apple seedlings were transplanted and grown under ordinary nursery conditions. One-half of the trees, taking alternate trees in each row, were dug at the end of one year after transplanting, and the remaining trees at the end of two years. In transplanting, the taproot of each seedling was cut off. Table I, in the appendix to this bulletin, gives the results of the experiment.

Twenty trees died from the effects of transplanting. It will be noted in Table I that there was an increase of crown-gall amounting to 0.8 per cent the first year and 0.1 per cent the second year after transplanting. At the same time there was an increase of 8.6 per cent of hairy-root the first year, and a decrease of 2.3 per cent the second year.

No experiment was made with seedlings grown from seed in which the trees were allowed to grow in the original place of planting for longer than a year. Nurserymen assert that there is little or no increase of disease after the first year, and that where seedling trees have been pulled with a tree puller at the age of 10 years in the seedling nursery there is no greater percentage of disease present than during the first year.

RELATIVE DEVELOPMENT OF THE DISEASE ON BUDDED AND ROOT-GRAFTED TREES IN THE NURSERY.

Development on budded trees.—In the propagation of varieties of apple trees by budding, seedlings at the age of 1 year are tipped; that is, the taproot is cut off. Then they are planted in rows in the nursery. These are budded the following summer. The slit in the bark where the bud is inserted is just above the surface of the soil. Crown-gall of both forms usually develops, if at all, at the two points where wounds are made, i. e., at the place where the bud was inserted and at the tip of the root. As a rule, much less crown-gall develops on trees propagated by budding than on those propagated by root grafting. Hairy-root develops more frequently than crown-gall on budded apple trees. The simple and the woolly-knot forms are common, the former developing on portions of the root below the surface of the ground and the latter at or near the surface, often from the region of the wound made in budding.

Development on root-grafted trees.—In the propagation of apple trees by root grafting, whether by whole root or piece root, more extensive wounds are necessarily made than are usual in budding. Wounds occur at the point of union where the scion piece is spliced to the root piece—at the lower end of the scion piece and at the upper and lower ends of the root piece.

Crown-gall, both soft and hard, like callus, develops usually at two points in the root graft—the lower end or tip of the scion piece (Pl. VI, figs. 1 and 6) and the lower end of the root piece. More than 90 per cent of the galls ordinarily develop at the former point. An exception occurs with some varieties, like the Wealthy, which are susceptible to the hard form of crown-gall and woolly-knot. Such varieties often develop the disease from the scion above the union (Pl. II, fig. 3).

It was found in experiments where the seedlings used for root grafting were carefully selected and only smooth roots used that hairy-root of the simple form was nearly eliminated. Such was not the case with the woolly-knot form.

It is asserted by practically all of the nurserymen from whom data have been collected, and the list includes nearly all of the large growers of apples in the United States, that apple trees propagated by budding yearling transplanted seedlings are as a rule much freer from both crown-gall and hairy-root than root-grafted trees.

Reports have been received from a number of nurseries giving the number of diseased trees among budded and root-grafted trees grown under similar conditions. These are combined and given in Table II, in the appendix.

From Table II it will be noted that there is a decrease of 3 to 39 per cent of disease on budded trees as compared with root-grafted trees. This is representative of the reports received. Two exceptions not given in the table must be mentioned: One occurred in Utah, the other in Virginia. In these two instances budded trees were reported badly diseased with crown-gall.

Under the conditions that generally prevail in the Central and possibly in the Eastern States, propagation by budding is advised at least in the case of varieties susceptible to crown-gall and woolly-knot. Owing to the fact that it takes one season longer to propagate an apple tree by budding than by root grafting, it will be more profitable to use the latter method of propagation in such States as California, where an apple tree is easily grown for market from root grafts in one season.

RELATIVE DEVELOPMENT OF EACH FORM OF THE DISEASE IN THE NURSERY.

Development on root-grafted trees.—In all of the larger nursery experiments records were kept of the number of apple trees diseased with each form of crown-gall and hairy-root. In the set of experiments conducted on cooperative plats 1 to 8 (see p. 78), 50,472 trees were grown from root grafts made from healthy scions and seedlings. Of these trees, 77.2 per cent was healthy, while 0.6 per cent was diseased with the soft form and 13.3 per cent with the hard form of crown-gall; with 2.6 per cent diseased with the simple form, 3.5 per cent with the woolly-knot form, and 2.8 per cent with the broom-root form of hairy-root. This result is considered representative the relative proportion of each form of the disease occurring up 1, 2, and 3 year old trees in the Mississippi Valley during 1905, 19 and 1907.

Development on budded trees.—No experiments were conducted budded trees in the nursery. Observation made at the time of d ging indicated that although budded trees develop much less cro gall than root-grafted trees, there is often a considerable devel ment of the forms of hairy-root. This may in part be due to t poor grade of seedlings which are often planted for the purpose budding.

RELATIVE DEVELOPMENT OF EACH FORM OF THE DISEASE IN T ORCHARD.

Four orchards were planted and studied during the present inv tigation. In addition, observations were made of the trees in number of orchards grown by others. The trees in experiment orchards 1 and 2 (for conditions of experiment see pp. 38 and 57 the appendix) were dug at the close of the period of investigatio at which time they were 8 years old. Notes were taken on the co dition of the roots of each tree in these orchards when it was plant in the orchard and again at the time of digging. Out of 234 ap trees that were healthy when transplanted into the orchards, 153, 65.4 per cent, remained healthy; 23, or 9.8 per cent, died; 11, or 4 per cent, developed traces of the hard form of crown-gall; and 4 or 20.1 per cent, showed traces of the woolly-knot and aerial fo of hairy-root. Out of 235 apple trees diseased with crown-gall the time of transplanting to the orchards, 73, or 31.1 per ce entirely recovered from the disease; 30, or 12.8 per cent, died; or 26.8 per cent, were diseased with the hard form of crown-ga and 69, or 29.3 per cent, developed the woolly-knot form of hai root, chiefly from the surface of former hard galls.

The results of the experiment, briefly stated in another form, these: Traces of the hard form of crown-gall developed on 4.7 cent of the healthy trees, but none of the soft form was foun Traces of hairy-root, chiefly of the woolly-knot form, developed 20.1 per cent of the healthy trees. Nearly a third of the trees (31 per cent) diseased with the hard form of crown-gall recovered; most another third (29.3 per cent) developed the woolly-knot fo of hairy-root from the hard form of crown-gall; and the remaini trees (31.1 per cent) were still diseased with the hard form of crow gall, which had not developed as rapidly as the growth of the tre

Orchard 1 contained both budded and root-grafted trees. Fo rows of healthy trees grown by budding were planted near four ro healthy trees of the same varieties grown by root grafting. Of budded trees planted, 5 became diseased, all with traces of the oolly-knot form of hairy-root. Of 31 grafted trees, 3 became dis- sed with traces of woolly-knot and 1 with the hard form of crown- ll.

In the results of these and other experiments in orchards 3 and 4, e following facts are prominent: That of the healthy trees trans- anted, about the same proportion became diseased as is usual the nursery, but only with traces of the disease, consisting mainly hard crown-gall and woolly-knot; that nearly a third of the trees seased with the hard form of crown-gall recovered; that the soft rm of crown-gall may develop into the hard form; and that the rd form of crown-gall in many instances developed into the woolly- not form of hairy-root.

STUDY OF NURSERY METHODS IN ROOT GRAFTING AS RELATED TO THE DEVELOPMENT OF THE DISEASE.

The slight effect of varying the depth of planting the union in root rafts.—The effect of deep planting upon gall and hairy-root forma- ion has been a matter of much discussion among nurserymen and thers. Howard (24) concludes from experiments "that the gall evelops least where the root is long, thus causing the point of union etween the scion and stock to be near the surface of the ground. specially is this true of clay soil."

A number of wholsesale nurserymen growing apple trees on a large cale assert that little benefit is gained by using short scions and long oots, and that a happy medium of length between the two is best. f a long scion is used, placing the union too deep in the soil, and at he same time using a short root piece, a poorer stand of trees and a slower growth takes place as compared with trees grown from equally long scions and root pieces or from short scions and long root pieces.

In order to test the influence of the depth of planting the union of grafts upon the occurrence of disease, two experiments were con- ducted in independent plat 1 (see pp. 77–78). In the first experiment root grafts were made with scions 6½ inches and roots 3½ inches in length, and these were planted with the union 6 inches beneath the surface of the soil. An equal number of grafts of each variety were made with the scions 3½ inches and the roots 6½ inches long and planted with the union 2½ inches below the surface of the soil. Sixty-four varieties of trees were used. Scions and roots from the same lot were used by the same workmen for making up each variety. They were planted in 1905. One-half of the trees were dug that year, taking every alternate tree, and the remainder in 1906, at the ages of 1 and 2 years, respectively, with the results shown in Table III, in the appendix, in which all forms of disease, both crown-gall and hairy-root, are combined. A large increase of hairy-root, but not of crown-gall, was noted the second year.

The second experiment was made with five varieties, Northwestern Greening, Grimes, Duchess, Walbridge, and Ben Davis, grafted on seedling roots of the same stock. The same number of grafts of each variety was made in two equal sets, one with scions 6 inches and piece roots 4 inches in length, the other with scions 4 inches and roots 6 inches in length. The former were planted with the union 5 inches below the surface of the ground, and the latter with the union 3 inches below the surface. An equal number of each set and of each variety were planted in cooperative plats 1 to 8 (see p. 78). A definite proportion of the trees, selected in a numerical series in the rows, was dug each year for three years, at the ages of 1, 2, and 3 years, respectively. The results are shown in Table IV, in the appendix, in which the number of trees and the percentage diseased with crown-gall and hairy-root are given.

From the results of these two experiments (see Tables III and IV) it will be noted that there was an actual increase of the disease in the case of the shallower planting of the union, in the first experiment amounting to 6.5 per cent and in the second to 2.5 per cent. The greatest development of crown-gall took place the first year and of hairy-root the first and second years. If the results of the two experiments be combined by adding the number of healthy and diseased trees in each, the result is 19.2 per cent of diseased trees where the union was planted deeper and 22.2 per cent where planted shallower, or a difference of 3 per cent in favor of the deeper planting of the union. This, however, is much more than offset and the practical results of the experiment are reversed by the fact that 13.2 per cent more trees were raised when planted shallowly than when planted deeply, or, in other words, there was a gain of 10.2 per cent by planting the union 2½ to 3 inches below the surface of the soil as compared with planting it 5 to 6 inches deep.

The slight effect from using different portions of seedling roots in root grafting.—In making piece-root grafts the root of the seedling tree is cut into two or more pieces. The opinion has been expressed by nurserymen that when the upper or collar piece of the seedling root is joined to a scion in a root graft there will be a greater prevalence of disease than when the lower or middle piece is used. In order to test this assumption a series of experiments was conducted in which equal numbers of grafts were made on the collar or upper pieces of the seedling roots and on the tip or lower pieces of the roots. Scions from five varieties of apples—Northwestern Greening, Walbridge, Grimes, Duchess, and Ben Davis—were used. These were grown in equal numbers in cooperative plats 1 to 8 (see p. 78). A definite proportion of these trees, selected in a numerical series,[a] was dug for each of three successive years—1905, 1906, and 1907—at the ages of 1, 2, and 3 years, respectively. The combined results from the eight plats are given in Table V, in the appendix.

The results of the experiments show an increase of hairy-root on trees grown from grafts made on the upper pieces of seedling roots. This is the portion of the seedling root that is most susceptible to the simple form. This increase of disease, 3.6 per cent, was more than offset by the greater stand of trees resulting from the use of the upper piece root, since an increase of 408 trees, or 15.9 per cent, was obtained. For practical purposes, then, the upper portion of the seedling root grows the greater number of healthy trees, in spite of the slight increase of disease. The tip pieces are smaller than the collar pieces, and root grafts made from them, being smaller, do not grow as vigorously as those made from collar pieces.

Increased development of the disease due to the use of seedlings diseased with hairy-root in making root grafts.—Two sets of experiments were conducted to determine to what extent the use of seedlings diseased with crown-gall and hairy-root would increase the development of the disease in root-grafted trees in the nursery.

Two series of eight experiments were conducted on cooperative plats 1 to 8. About three thousand apple seedlings diseased with the simple form of hairy-root (Pl. IX, fig. 2, Nos. *G* and *H*), but entirely free from galls, were selected for these experiments. Whip or tongue grafts were made, all of the pieces of the roots from these diseased seedlings being used. Some of these pieces from the root tips were apparently healthy. All of the pieces from the upper or collar pieces were diseased with hairy-root. As a control, an equal number of root grafts were similarly made on roots from healthy seedlings of the same diameter as the hairy-rooted seedlings selected from the same stock. These two sets of root grafts were made with scions from the following varieties of apple: Fameuse, Scott Winter, Wolf River, Jonathan, and Salome. A definite proportion of the trees grown from these root grafts was selected in a numerical series and dug at the ages of 1, 2, and 3 years. The results of the experiment are summarized in Table VI, in the appendix.

A second and smaller series of eight experiments was prepared and conducted the same as the first set, except that scions were used from the Yellow Belleflower apple. Two equal sets of grafts were prepared from the same stock of seedlings, one set made on piece roots from seedlings with smooth roots and one on piece roots from seedlings with hairy roots of the simple form. These were grown also in cooperative plats 1 to 8. Table VII, in the appendix, gives the combined results of the experiments.

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[a] In this bulletin the term "numerical series" means the selection of trees in sequence, as every second tree, every third tree, etc., depending on whether one-half, one-third, etc., of the trees were dug each year.

These experiments yielded three positive results:

(1) The use of root pieces from hairy-rooted seedlings did not increase the amount of crown-gall, since in the two sets of experiments 7.3 and 2.6 per cent of crown-gall developed on trees grown from hairy-root pieces, as compared with 12.6 and 7.3 per cent, respectively, on trees grown from smooth-root pieces.

(2) A greatly increased stand of trees resulted from the use of hairy-root pieces, since 4,956 trees were grown from grafts made on such pieces, as compared with 3,802 grown from the same number of grafts made with smooth-root pieces, an increase of 30.4 per cent.

(3) The use of hairy-root pieces resulted in an increased number of trees diseased with hairy-root, since 77 and 83.7 per cent of the trees grown from grafts made with such pieces were diseased with hairy-root as compared with 10.2 and 8.9 per cent from grafts made with smooth-root pieces.

The reason for the increased stand of trees from the root grafts on hairy-root pieces is as follows: Since the season was dry and unfavorable for the rooting of the grafts at the time of planting in the first experiments, the hairy-root grafts rooted more readily, and, as a results, fewer of them died and an increased stand resulted. The results of the following experiments are given in proof of this statement. It was found by a small experiment with cuttings from seedlings diseased with simple hairy-root that 25 per cent of such cuttings rooted (Pl. VII, fig. 1) and became trees in a bed in the greenhouse, whereas only 5 per cent of cuttings taken from smooth seedlings of the same lot and planted in the same bed with the former cuttings took root, and then feebly. This experiment was made with 100 cuttings of each kind on an ordinary greenhouse bench with 8 inches of soil, without bottom heat.

The trees grown from the different varieties of apples grafted on the hairy-root seedlings behaved differently in their root formation. Those varieties which rooted readily from the scion or stock—for example, the Fameuse and the Salome—sent out smooth roots, with very few exceptions, above the hairy-root piece (Pl. VII, fig. 3). Such trees very often formed a well-balanced root system from the stock, and there followed the second year an atrophy of the hairy-root pieces, which did not injure the tree. In the case of varieties that did not root readily from the scion—for example, the Jonathan and the Scott Winter—most of the roots were poorly balanced and sprang from near the union (Pl. VII, fig. 4). On the whole, nearly two-thirds of the trees grown on the hairy-root pieces would be graded as culls, especially those grown from the Jonathan, the Scott Winter, and the Wolf River varieties, and the use of such seedlings for grafting must be condemned, the same as those diseased with crown-gall.

In these experiments a careful count was made by the writer of the number of trees diseased with each form of crown-gall and hairy-root. In the first series of experiments, of the 3,976 trees grown from grafts made from seedlings diseased with hairy-root of the simple form, 0.5 per cent was diseased with the soft form and 6.8 per cent with the hard form of crown-gall, while 69.1 per cent was diseased with the simple form, 5.2 per cent with the woolly-knot form, and 2.8 per cent with the broom-root form of hairy-root. Of the 2,864 trees grown from grafts made from seedlings with smooth roots, 0.7 per cent was diseased with the soft form and 11.9 per cent with the hard form of crown-gall; and 2.8 per cent was diseased with the simple form, 4.1 per cent with the woolly-knot form, and 3.3 per cent with the broom-root form of hairy-root.

Increased development of the disease due to the use of seedlings diseased with crown-gall in making root grafts.—In connection with the previous set of experiments (see Table VII, in the appendix), in addition to the two sets of root grafts prepared for that experiment, a third set was prepared in which the same stock of scions on root pieces cut from seedlings diseased with the soft form of crown-gall was used. Care was taken in each case to cut away the portion of the root containing the origin of the gall, so as to use the apparently healthy portions of the roots. These root grafts were made, planted, and grown with those in the previous experiment, the same set of root grafts being used for a control. The results of the experiment are given in Table VIII, in the appendix.

The results of this experiment prove that the use in making root grafts of apparently healthy root pieces from seedlings diseased with soft crown-gall increases the amount of the disease, the increase in this case amounting on an average to 12.9 per cent of crown-gall and 2.3 per cent of hairy-root or a total of 15.2 per cent.

In some nurseries workmen do not always discard seedlings diseased with crown-gall, but cut away the galls and use the remaining portion of the root, as was done in the experiment just given. Such a practice must be condemned, since it increases considerably the development of the disease in root-grafted trees.

The slight effect of using for root grafts scions from younger and older trees.—An experiment was conducted to determine the effect on the development of crown-gall and hairy-root of grafts made with scions taken from fruiting orchard trees as compared with those made with scions taken from yearling trees in the nursery. Two sets of grafts were made on the same lot of seedling roots—one from scions selected from orchard trees 12 years old, the other from yearling nursery stock of the Northwestern Greening variety. These were grown in cooperative plats 1 to 8. Table IX, in the appendix, gives the results as tabulated each year for three years, a definite proportion of the trees being dug each year at the ages of 1, 2, and 3 years, the trees being selected in a fixed numerical series in the row.

It will be seen from Table IX that there was an increase of 2.4 per cent of crown-gall and of 3.1 per cent of hairy-root in the case of trees grown from scions taken from rapidly growing yearling trees in the nursery as compared with trees grown from scions of harder wood taken from fruiting orchard trees. The difference, however, is more than counterbalanced by the increased stand of trees, 7.8 per cent, obtained from the scions from yearling trees. It must be concluded that the difference, though small, is not in favor of the use of scions with softer wood from young and rapidly growing trees.

No effect from leaving a bud near the lower end of the scion in making root grafts.—It has been asserted by some of the older workers in nurseries that the increased amount of crown-gall on the union at the point or lower end of the scion is due to cutting the scions so that a bud is left near the lower end. This matter was tested in an experiment, with the result that the assertion was found to be without facts to support it.

In this experiment scions from the variety Jonathan were cut in two ways: One set was made without a bud at the lower end of the scion, another equal set with a bud in close proximity to it. These were grafted on healthy seedling roots of the same lot and planted in ordinary soil in independent plat 1 (see p. 77). Two lots of one hundred root grafts of each kind were planted. Of the trees grown from grafts with buds on the lower ends of the scions, 19.2 per cent were diseased, and of the trees grown from those without buds, 21.1 per cent were diseased, showing positively that the bud has no direct influence in increasing the amount of disease.

Experiments comparing American and foreign-grown apple seedlings.—There exists in many localities the opinion that seedlings grown from foreign seed are less apt to develop crown-gall and hairy-root than those grown from American seed. To test this theory, two equally large sets of grafts were prepared, scions from the following varieties of trees being used: Maiden Blush, Winesap, Baldwin, Yellow Transparent, and Missouri. One set was grafted on seedlings grown from apple seed imported from France, the other on seedlings of the same grade grown in the same field from American apple seed. The grafts were divided into eight equal lots and planted in cooperative plats 1 to 8. A definite proportion of the trees, selected in a numerical series, was dug each year for three years. Table X, in the appendix, gives the combined results of the experiment.

The results of the experiment were in favor of the use of American seed for growing seedlings, since there was an increase of 4.9 per cent of crown-gall on the trees on roots grown from French seed, and, on the other hand, an increase of 1.3 per cent of hairy-root on trees grown from roots from American seed. If we combine the number of trees diseased both by crown-gall and hairy-root, there will be found an increase of 3.6 per cent of disease, due to the use of French seed. This difference is further accentuated by the number of trees grown from the same number of grafts on the roots from American seed, 2,255 as compared to 1,802 on roots from French seed, or a gain of 25.1 per cent in favor of the use of the former. The experiment proves that the assumption that the use of American seed in growing seedlings tends to increase the development of crown-gall is erroneous and it indicates a superiority in seedlings from American seed.

The use of seedlings from old nursery districts for making root grafts may not increase the development of the disease.—It has been asserted by some growers of nursery stock that seedlings purchased from regions where they had been grown year after year, and especially from Kansas, developed more crown-gall than those grown in new regions in soil where nursery stock had not been previously grown. To test the matter, two lots of grafts were made from the same stock of scions, including the following varieties: Yellow Transparent, Baldwin, Winesap, Maiden Blush, and Missouri. One set was made on seedling roots grown from French apple seed in the Kansas River valley, near Topeka, Kans., on soil subject to inundation from the river and overflow from neighboring nurseries and on which nursery stock had been previously grown; the other set was from another stock of seedlings grown from the same stock of seed by the same nursery company in a new locality near Lincoln, Nebr., on soil which had been cultivated in field crops for a number of years and on which nursery stock had never been grown. This set contained half as many root grafts as the former. The grafts were made, planted, and grown with the same care as in all of the experiments. They were grown on cooperative plats 1 to 8, and a definite proportion, selected in a numerical series in each row, was dug each year at the ages of 1, 2, and 3 years. Table XI, in the appendix, gives in a condensed form the results of the experiment.

In giving the results of this experiment it must be noted that the conditions under which the seedlings for the experiment were grown were not quite comparable for two reasons: The localities where they were grown (Kansas and Nebraska) varied in latitude, and the soil conditions were not quite the same, since these seedlings were grown in different valleys. The trees from the two sets of grafts made from these seedlings, however, were grown under similar conditions, and the results of the experiment are of value, since they show what variation may be expected from seedlings grown in different localities and since they disprove the prevalent idea that Kansas seedlings are more apt to develop crown-gall than others. The results show a decrease of 3.4 per cent in crown-gall and of 1.1 per cent in hairy-root on trees from grafts on Kansas seedling roots. This is almost entirely offset by the increased stand of trees, 3.1 per cent, obtained from the trees grown from grafts on Nebraska seedling roots. The experiment, then, yields no positive proof of an increase of the disease where seedlings are purchased from localities where nursery stock has been grown for years.

Heavy wet soils favor the development of crown-gall in the nursery.— The consensus of opinion of nurserymen, based upon observation, has been that heavy wet soils underlaid with or composed largely of clay favor the development of crown-gall. No extensive set of experiments on this subject has been recorded. The most extensive experiment recorded in scientific publications is that of Howard regarding the increase of crown-gall due to clayey soil as compared with loess.

A large number of experiments have been conducted by the writer on different kinds of soils, only two sets of which were conducted in the same locality. These were on cooperative plats 1 and 2. Plat 1 consisted of a low wet tract of land, composed of a colluvial clay loam laid to a depth of 3 to 4 feet on a stratum of yellow clay. Plat 2 was an upland, well-drained, light clay loam of about equal depth, sloping gently to the south. The two plats were planted with an equal number of root grafts made from healthy stock and prepared in equal lots from twenty-four varieties of apples. The names of these varieties are given on page 85. One-third of the trees, selected in a numerical series, were dug each year for three successive years, at the ages of 1, 2, and 3 years. The results are given in Table XII, in the appendix.

Nearly the same amount of disease occurred in the two plats, 24.9 per cent in plat 1 and 24.1 in plat 2. There was a preponderance of 5.3 per cent of crown-gall on the heavier, wetter soil, and 4.5 per cent of hairy-root on the higher, drier soil. Without regard to the cause of the different forms of the disease, the usual rule with regard to the increased production of roots in drier soils holds good in these experiments. The well-drained upland soil in plat 2 yielded 20.2 per cent more good trees than the other plat. These, however, were at least a third smaller in size.

Six other cooperative plats, 3 to 8, were planted with experiments identical with those in plats 1 and 2, since the root grafts for each experiment in these plats were all made at one time in the same nursery, divided into eight equal lots, and planted in each of the plats. The location of each plat and a description of the soil are given on page 78. It was noted that more diseased trees occurred on the plats with the wettest, heaviest soils. The results from the two plats with the heavier, wetter soils and from the two plats with the lighter, better-drained soils are given in Table XIII, in the appendix. The wet, heavy soils gave from 8.1 to 11.1 per cent more diseased trees than the light, dry soils. The highest percentage of disease in a number of smaller experiments has invariably occurred on wet, heavy soils. It therefore appears that such soils are more favorable to the development of crown-gall.

Period for the maximum development of crown-gall and hairy-root in the nursery.—After compiling the data from a large number of experiments, involving many trees dug at different ages, certain regular variations were noted in the amount of crown-gall present at different ages on root-grafted trees in the nursery under the conditions of experimentation.

The results which follow are compiled from seven large sets of parallel experiments carried on in four of the cooperative plats—1, 2, 3, and 4 (see p. 78). The root grafts for each set were made from carefully selected healthy stocks of scions and seedlings at the same nursery, divided into four equal parts and planted in the four cooperative plats just named. Twenty-four varieties of apples were used, the same as are given in Table XXI, page 85, in the appendix. One-third of the trees in each plat, selected in a numerical series in each row, were dug each year, at the ages of 1, 2, and 3 years. The results are given in Table XIV, in the appendix.

The results in Table XIV indicate plainly that in the nursery and under the conditions given root-grafted trees developed crown-gall chiefly during the first year, and that during the next two years many of the trees threw off the disease, which decreased the second year from 26.7 per cent to 9.1 per cent, and the third year from 9.1 to 4.7 per cent. This table also shows that the development of hairy-root took place chiefly during the first year, but increased considerably the second year, 3.1 per cent, with little increase the third year, 0.1 per cent.

An objection to making such conclusions from average results may be offered for the reason that the average may be that of two widely differing extremes, either of which might include the results of a large number of the experiments, and that such extremes if taken separately would warrant the formation of entirely opposite conclusions. This objection can not hold here, since all of the sets of experiments gave approximately the same general results as the average, and even the smaller units or variations combined in these sets, with very few exceptions, gave the same results. None of these exceptions varied widely from the general trend of the results. A reference to the tabular results of a number of other experiments given both earlier and later in this bulletin will lead to the same conclusions as are drawn from Table XIV.

EFFECT OF THE DISEASE UPON APPLE TREES.

OBSERVATIONS BY OTHERS ON CROWN-GALL.

It has generally been held by pathologists that crown-gall is very destructive to trees. Frank (14), in discussing the Wurzelkropf on apple trees in Germany, notes that trees with very large galls show a weaker growth of the trunk and branches, probably due to the fact that the swellings absorb considerable nutritive substance. Wickson (77), in discussing the general subject of root knots on fruit trees, makes the following statement:

> Probably during the last twenty years hundreds of thousands of such trees (referring to trees with galls) have split and died in the best soil and with the best treatment. If disease has stunted the growth of a young tree, pluck it out and plant a new one. If the knots are found on larger trees which are making satisfactory growth in spite of them, remedial measures should be tried. The final result seems to depend upon whether the natural or the diseased growth secures ascendancy early in the life of the tree; but apricot trees have been taken up after thirty years of satisfactory growth and bearing and found to have roots badly affected with the knots.

In the same bulletin Woodworth makes this statement:

> The presence of a gall at the crown of the plant seems to effect an obstruction to the flow of the sap, and in this way a tree or vine becomes weakened and finally dies. The gall generally attacks small plants, but not always, and it often takes a number of years before the plant is killed.

Yates (80), in speaking of the crown-gall, does not consider the same a disease.

Selby (50), referring to apple crown-gall, says: "It seems unlikely that such affected trees will be worth planting, and all of them suffering with this trouble should be burned."

Stewart, Rolfs, and Hall (64), make the following statement: "We find crown-gall not uncommon on apple trees in the nurseries in western New York, but we know of no case where it has caused material loss. * * * We would recommend that all trees showing the least trace of the disease be rejected; for, although we have never seen any ill effects from the planting of affected apple trees, it appears probable that the disease may thus be spread." They refer to a nurseryman who writes that he planted a row of healthy apple trees and at the same time a row of trees affected with crown-gall, and who states that after two years the trees with the crown-gall had made just as good a growth as the healthy trees near by.

Garman (16), expresses an opinion to the effect that crown-gall ees can never be very profitable, since in their enfeebled condition ey will not bear well.

Alwood (2), who made an extensive study of this disease, in his troduction, referring to the results of his experiments, states that ese results "seem to point clearly to the conclusion that every anter must be prepared to detect this trouble, and exclude it from s orchard plantings." Commenting further on the results of his periments, Alwood says: "Our observations in more recently anted orchards show that it is not usual for trees showing an attack this trouble to form a normal root system; the root development weak and confined to the surface. * * * We are also of the inion that badly diseased trees, such as are now very commonly und in nursery stock, will not ordinarily come into fruiting." In lecture before the Maryland State Horticultural Society Alwood (4) quoted as saying, in speaking of orchard trees diseased with crown-ll, that "they have scarcely grown at all, although they have been ltivated for five years."

Butz (7), in speaking of eleven apple trees planted on the Pennsylnia Agricultural Experiment Station grounds, reports that after o years' growth the trees showed "immediate injury, due to the lls."

Norton (34) states that "trees affected with crown-gall set out in e college yard have never done well." In a later publication (37) makes the following statements:

> The galls, when they occur on the main root, may interfere with the transfer of the p in the tree, and thus weaken it. The constriction by the gall may cause the tree fruit too young, or to overbear; they cause abnormal root development, and thus nder the growth. They are often so well developed as to cut off and cause the ath of the taproot, which is almost always killed when affected throughout by the iry-root condition. The tissue of the gall may decay and form an entrance for od-rotting fungi which will soon destroy the tree.

R. E. Smith (55) reports apple crown-gall to be very common in urseries, but apparently it "does not result as seriously in orchard ees as with the similar disease on stone fruits."

Morris (33) makes the following assertion: "The trees affected ith galls at the crown are doomed to death sooner or later. Someimes the trees are completely girdled and starved to death, at other imes the root of the tree is so weakened that it is easily broken by ind."

Sandsten (48), concerning crown-gall, says:

> Some kinds of fruit trees are less resistant than others. For example, it is well nown that a young peach tree infested with the disease will live for a relatively short ime, while apple trees may live for a number of years * * *. Perhaps the chief eason why fruit growers fear the disease is that just about the time when the trees

become profitable, or when the trees have attained the age of 8 or 10 years, they beg to rot off at the crown and die. This is especially true of apples. I have particul in mind a thriving orchard in the Southeast of 25 acres of apple trees, 11 years ol which bore a few crops, then all at once about half of them began to fail. Upo examination it was found that the trees had been killed by crown-gall.

Van Deman (70), in a discussion on fungous diseases, is quoted a follows, in a Virginia Horticultural Society Report, in answer to question concerning an apple tree diseased with crown-gall: "Yes, si it lives right along until it begins to bear, and then it begins to dwindl and you wonder why. * * * It doesn't attain the size of othe trees, though sometimes it is fairly vigorous. The gall will, however keep on growing for years and years."

Popenoe (44) reports the following experiment: A lot of Ben Davi trees, 2 years old, one half having visible galls on the roots and th other half being similar trees without galls, were planted a few years ago on rich, second-bottom, level, black land on the station grounds at Manhattan. At the time the report was made, in 1903, Popenoe says: "There is practically no difference in the growth above ground of the trees of the two lots, and of the trees originally clean of galls, ome are now affected."

OBSERVATIONS BY OTHERS ON HAIRY-ROOT.

In the various citations as to the effect of crown-gall on trees there is little or no reference to hairy-root. Stewart, Rolfs, and Hall (64), referring to the hairy-root of seedlings, which we have designated as the simple type, state that "affected trees are worthless for planting."

Garman (16), discussing a knot disease of apple trees which is evidently the aerial form of hairy-root of the woolly-knot type, makes the following statement:

> It undoubtedly weakens the trees attacked, but does not keep them from bearing in all cases, and when but few knots are present the trees show no other outward evidence of disease.

In a letter dated September, 1907, Garman writes as follows concerning the disease: "I am satisfied it is not spreading, and I do not regard it as particularly destructive, although I have no doubt it affects the health of the tree when a great many of the knotty growths are present."

The gist of the foregoing quotations, which include a summary of nearly everything that has been published on the effects of crown-gall and hairy-root in this country, is that in the opinion of a majority of those observers who have investigated these forms of disease, they are to be considered dangerous and likely to weaken or kill affected trees. This general opinion concerning the nature and effect of crown-gall of apple trees seems to have gained ground largely as a esult of the opinion expressed by Toumey (68) concerning crown-all of the almond, who proved that it may be highly contagious and xtremely destructive.

Beginning with the date of Toumey's paper on crown-gall of the lmond, without waiting for further proof, the general assumption as been that the effect of crown-gall upon the apple tree is identical ith that of this disease upon the almond. With the general opinion revalent in most parts of the country, vigorous methods have been dvocated very generally by pathologists, entomologists, nursery nspectors, and others. Stringent laws have been enacted for stamp-ng out the disease, with the assumption that the disease of the apple s as injurious as that of the stone fruits.

In summing up the few opinions which were given from actual experiments, it may be well to suggest that in all probability the effect of root-rot has been confused with that of crown-gall. It is well known that root-rot attacks orchards in many portions of the apple-growing belt, especially in the South and the Southwest. In collecting accurate data on the effect of crown-gall and hairy-root it is absolutely necessary that each individual tree be examined and the condition of the roots noted before drawing any conclusions as to the cause of the death. A study of the connection between root-rot and crown-gall is also necessary. All of the trees in the orchard experiments of the writer have been free from root-rot, but borers were present in orchards 1 and 2 and killed all of the trees that died after the first year, but attacked healthy and diseased trees alike. In forming conclusions as to the cause of the death of an apple tree, not only root-rot but also these borers should be taken into account, since they apparently attack smooth-rooted trees as often as those diseased with crown-gall and hairy-root. These insects bore beneath the bark into the wood of the tree and allow root-rot fungi to enter the wounds made by them. Quite often death results in a couple of years from the first attack.

Wherever an orchard has been reported as dying in a short time from crown-gall it will be well to look deeply into the causes of the death of the trees before accepting the report as a scientific fact. In the writer's opinion, which is based upon exact orchard experiments, crown-gall never kills an apple tree suddenly, and where no other disturbing factor enters, it may not be able to kill it at all. The wounding of a projecting hard or soft gall may enable wood-rotting organisms to enter the tree and kill it. Again, the presence of gall tissues may the better enable insects to attack the tree, but in the writer's experiments he found no proof that diseased trees were more subject than healthy trees to the attacks of insects and wood-rotting fungi.

EXPERIMENTS ON THE EFFECT OF THE DISEASE ON APPLE TREES.

EFFECT ON SEEDLINGS NOT UNIFORM.

No extended experiments have been made to determine the effect of crown-gall and hairy-root on seedlings. From small experiments and from observation the following conclusions have been reached: On yearling seedlings with relatively large galls encircling the root (Pl. II, fig. 2) or with a very abundant formation of fine side roots (Pl. III, fig. 1), such as accompany extreme forms of hairy-root, there is a perceptible stunting of the growth of the tree. Where the galls are small and the hairy-root formation is not extensive, no apparent effect on the growth is noted. In the latter case, as the trees grow older, they may outgrow the effects of the disease.

The aerial form of hairy-root (stem tumors) was found in the autumn of 1908 on 40 trees in a block of 500 8-year-old seedling apple trees in a pedigree orchard near Mitchell, Ind., belonging to the Indiana Agricultural Experiment Station. These were first reported in a letter by Prof. C. G. Woodbury, of that station. Six of these trees bore from 8 to 25 large, rough knots (Pl. V, fig. 1), in some cases encircling the tree. None of these trees was quite as large as the neighboring trees. No difference in size was noted in the other 34 diseased trees.

One striking effect of hairy-root of the simple form should again be noted. Seedlings diseased with this form are enabled to root more readily than healthy seedlings. Cuttings taken from such seedlings root more readily than those from healthy seedlings (see p. 24). Such cuttings usually develop into trees (Pl. VII, fig. 1), affording to some extent a method of propagation not ordinarily used and not to be recommended.

SLIGHT EFFECT ON GRAFTED TREES IN THE NURSERY.

The same observations made on the effect of crown-gall and hairy-root on seedling trees apply to young grafted trees, except that the stunting, as a rule, is not nearly so marked. A great variation in effect is shown, since some diseased trees exhibit as great or even a greater vigor of growth than healthy ones. On the average, however, trees in the nursery rows that are diseased with the simple form of hairy-root are not quite so tall as smooth-rooted trees, and those with the woolly-knot form may be taller. Those affected with forms of crown-gall are somewhat shorter than those with hairy-root.

In order to determine the effect of the disease on the height of trees in the nursery rows, measurements were taken of 18,042 1 and 2 year old root-grafted trees grown in a number of the experiments mentioned earlier in this bulletin. These trees were grown in cooprative plats 1 and 2, in southwestern Iowa; plat 3, in eastern Nebraska; plat 4, in western Illinois; and plat 6, in eastern Kansas. In five of these sets of experiments, the results of which are given in Tables XV and XVI, in the appendix, a definite proportion of the trees, selected in a numerical series in the row, was dug at the age of year, and the remainder at the end of the following season.

From Tables XV and XVI it will be seen that the average height of healthy trees in the experiments at the age of 1 and 2 years was 37.2 and 56.4 inches, respectively, as compared with 33.5 and 51.3 inches for trees diseased with crown-gall and 34 and 53 inches for trees affected with hairy-root. In other words, galled trees were only ninety hundredths and ninety-one hundredths and hairy-rooted trees ninety-one hundredths and ninety-four hundredths as tall as healthy ones. A few measurements of root-grafted trees made at the end of three years indicate that approximately the same rate for each still held at the end of the third year's growth. A few measurements were made of the diameter of healthy and diseased trees of some of the rows in each experiment, but time would not permit of the measurement of all. It was found that the ratio of the diameters was approximately the same as that of the heights, viz, almost 10 to 9.5 for healthy and diseased root-grafted trees in the nursery.

In conclusion it must be said that taken collectively the forms of crown-gall and of hairy-root do have a slightly stunting effect on root-grafted trees in the nursery during the first three years, and for that reason, at least, such trees are not equal to healthy ones for planting in orchards. This conclusion as to hairy-root is given with the following modifying statements:

(1) The effect of the simple form of hairy-root in stimulating root production in root grafts is described on a previous page. When cuttings are taken from trees diseased with the knots or the aerial form of hairy-root and planted or used as scions, root formation is more abundant than with healthy cuttings. Roots are thrown out readily, especially from the young knots, producing the woolly-knot form (Pl. V, fig. 2, and Pl. VII, figs. 1 and 2). Such trees are sometimes more vigorous growers for a time than healthy trees. The final effect is not yet known.

(2) The abnormal root production of the woolly-knot form often stimulates the growth of grafted trees, and, as a result, such trees frequently become the largest in the row. This stimulation often continues after the trees are planted in the orchard. The largest tree in experimental orchard 1 was diseased with woolly-knot (Pl. IX, fig. 1).

LITTLE OR NO EFFECT ON ORCHARD TREES SHOWN IN EXPERIMENTS.

Experiments by others.—Orchardists and nurserymen, as well as investigators, differ in their opinions as to the effect of crown-gall and hairy-root on the apple tree. It would be interesting to cite the statements of a number of nurserymen and orchardists, but it will be better to give data from orchards grown by them with diseased trees.

The owners of one orchard, Marshall Brothers, at Arlington, Nebr., reported in a letter dated January 25, 1909, as follows:

> We have 29 Wealthy apple trees that we planted thirteen years ago. All of them were more or less galled, some galls being nearly as large as a hen's egg. These trees have grown well and have done splendidly. We have noticed no difference between these and other Wealthy trees of the same age in growth and bearing. They have given almost annual crops the last five or six years, and two or three very heavy crops.

The owners of a second orchard, of 10 acres, at Troy, Ohio, reported May 16, 1907, as follows:

> The orchard you ask about was planted five years ago this spring and consisted of Yellow Transparent apples which were badly infested with crown-gall and aphis. Inasmuch as the authorities in this State are opposed to the use of trees thus infested, we have discontinued the growing of apples at this place, and therefore did away with the orchard this spring. However, we wish to say the trees were thrifty and in good growing condition, and we do not believe there could be any objection to the showing they made. There was some fruit on this orchard last season.

A third orchard is reported upon by Charles C. Bell, of Boonville, Mo., January 4, 1908. He states that an orchard of about 20 acres was planted in 1900 with 2-year-old trees diseased with crown-gall, after samples of the trees had been condemned by experts, as unfit for planting. He says: "To-day these trees which were condemned * * * are a beauty to behold; they are healthy and strong and ready to bear fruit."

A fourth orchard was planted and grown in 1902 near Mountain Grove, Mo., by F. A. Faurot, a collaborator of the Bureau of Plant Industry. This experiment was in cooperation with the Missouri Fruit Experiment Station at that place. By permission of the director of the station, Paul Evans, Mr. Faurot furnished the data for publication. The orchard is planted in two plats, one sloping gently to the east, the other to the north. The soil is a clay loam. In the first plat 275 apple trees were planted, one-fifth of which were diseased with crown-gall. The diseased trees were in a separate row, but were of the same varieties and of the same stock as the healthy ones. The second plat consisted of 96 apple trees, one-third of which were plainly diseased with crown-gall. In company with Mr. Faurot, the writer visited the orchard in the autumn of 1908. No difference could be detected in the growth and appearance of the trees in the diseased rows of trees when compared with those in the healthy ones. Relatively, in number, no greater proportion of the diseased trees had died in six years of growth. No evidences of premature development, such as early bearing, stunted growth, etc., were noticed in any of the diseased trees.

A fifth orchard, belonging to the Arkansas Agricultural Experiment Station, located at Fayetteville, Ark., has been under the observation of the writer for five years. This orchard is 15 years old and was planted as an experiment to test varieties of apples from a horticultural standpoint. Twelve out of a hundred trees in this orchard, mostly Russian varieties, have developed the aerial form of hairy-root, with no apparent effect as yet upon the growth or the fruiting of the trees.

A sixth diseased orchard is situated near Mitchell, Ind., on the farm of the Burton Fr[illegible]t Company. Among other older trees there are planted over two hundred Benoni apple trees now 8 years old. This orchard was visited by the writer in the autumn of 1908. More than half of the Benoni trees are diseased with the aerial form of hairy-root, with little or no apparent effect, as yet, on their growth. Mr. Joseph A. Burton, superintendent of the orchard, asserts that many of the knots disappear as the trees grow older, but that their immediate effect is to make the trees bear younger. In an older orchard belonging to Mr. Burton there is a thrifty 25-year-old Chenango apple tree that has been diseased with the aerial form of hairy-root for years, with no effect upon its fruitfulness.

In summing up the data from these orchards, the results show that crown-gall and hairy-root have but little immediate effect on the growth of trees in the orchard. Orchards that were reported dying from disease have been examined by the writer, but the immediate causes on examination have proved to be heart-rot and root-rot, usually accompanied in unfavorable soil conditions by poor drainage, neglect of cultivation, etc. These diseases apparently attack and kill the trees originally healthy, without regard to the presence of crown-gall or hairy-root.

Experimental orchards.—The orchard experiments conducted for the study of the disease were four in number. The location of these orchards, designated as orchards 1, 2, 3, and 4, and a description of the soil in each, with the methods of experimentation, are given on page 79.

Orchard 1 was planted with trees of the following varieties: Ingram, Gano, Collins, and York Imperial, grown in a nursery in eastern Missouri. It was planted with 112 healthy apple trees (Pl. III, fig. 3) and 96 diseased with the hard form of crown-gall, the galls being near the crowns of the trees, just below the surface of the soil as they grew in the nursery (Pl. I, fig. 1). This orchard was on well-drained soil, and the healthy and diseased trees were planted in alternate rows.

Orchard 2 was planted in a soil similar to that of orchard 1, except that it was situated at a lower elevation and was subject to seepage.

It was planted with the same varieties, but the healthy trees, 122 in number, were planted in blocks of several rows, rows of healthy trees alternating with rows consisting of 139 diseased trees. Both orchards were cultivated across rows, from diseased to healthy trees, to facilitate the spread of disease by cultivation. One block of 36 diseased trees of the Collins variety in this orchard was composed of trees diseased with the soft form of crown-gall, the other varieties being diseased with the hard form. Most of the galls were from 1½ to 2 inches in diameter.

Orchards 1 and 2 were cultivated with ordinary care, receiving no special attention. The trees were planted thickly and stood 8 by 9 feet apart. The soil was not the best, owing to the fact that it had been cultivated to grain crops without fertilization for many years. No fertilizer was used, natural soil conditions being preferred. The growth of the healthy and the diseased rows was so nearly uniform that on repeated tests trained pathologists could not pick out the rows of diseased trees. Photographs of representative rows of trees were taken at the age of 6 years (see Pl. X).

Owing to a fire which killed many of the trees in orchards 1 and 2, the experiments had to be discontinued, and the trees were taken up when they were 8 years old; that is, after they had grown for six seasons in the orchards. Just before the trees were taken out, the trunk of each was carefully measured at a height of 6 inches above the surface of the ground. At the time of removal careful notes were taken of the condition of the roots as to increase of disease, recovery therefrom, forms of disease, etc. The results of the experiment are given in a condensed form on pages 20 and 57 and in Tables XVII, XVIII, and XIX, in the appendix. Table XVII gives the average diameter of the healthy and the diseased trees at the time they were dug.

It will be seen from Table XVII that the effect of crown-gall and hairy-root on the trees in the experiment was to diminish very slightly the diameter of the trunks. The trees with healthy roots had developed in six years an increase in diameter of six one-hundredths of an inch greater than those diseased with hairy-root, and of twenty-nine one-hundredths of an inch greater than those diseased with crown-gall. These diseases are thus shown to be very slightly detrimental to the growth of orchard trees during the first few years, and the assertions of many to the contrary are disproved.

In orchards 1 and 2, during the six seasons of growth the number of healthy trees that died was 23 out of 234, or 9.8 per cent, and of diseased trees it was 30 out of 235, or 12.8 per cent, indicating that the presence of the disease may have slightly increased the death rate. During the first four years 9 healthy and 9 diseased trees died.

Of these 5 healthy and 7 diseased ones died from the effect of transplanting to the orchard. During the fifth year 10 healthy and 12 diseased trees died, and during the sixth year 4 healthy and 9 diseased trees died. It should be noted, however, that all of the trees that died during the fifth and sixth years and 3 trees during the irst four years were killed by borers encircling the trunk near the surface of the ground. In no case could their death be directly attributed to crown-gall or hairy-root, nor can it be said that borers prefer the diseased trees to any marked extent.

Tables XVIII and XIX, in the appendix, show the number of healthy and diseased trees of each variety planted in orchards 1 and 2, as well as the number of each that died during six seasons of growth. The diseased trees of the variety Collins in orchard 2 had soft galls on the roots. All of the other galls were of the hard form.

A third orchard, designated as "orchard 3," was planted in the latter part of April, 1907, with 1,108 well-rooted apple trees of a number of varieties selected from trees grown in experiments in the nursery. Of these 572 were healthy, 354 diseased with hairy-root (Pl. I, fig. 2), and 117 diseased with crown-gall of both the hard and the soft forms. The trees were transplanted after the buds were greatly swollen, and a month of dry weather ensued just after the planting. As a result, the loss from transplanting was heavy. A fire in the autumn of 1908 killed many of the trees and ruined the experiment. The trees were then dug, no notes being taken at the time of digging as to the condition of the roots. The trees that died in 1907 and 1908 are enumerated in Table XX, in the appendix.

By combining the data for 1907 and 1908 in Table XX, it is found that in two years 33.4 per cent of the healthy trees died, and at the same time 37.3 per cent of those diseased with crown-gall and 25.1 per cent of those diseased with hairy-root. Again it must be said that the reason for the increased vitality of the trees diseased with hairy-root is the greater tendency to throw out roots. This has already been mentioned in the case of seedlings affected with hairy-foot (see pp. 24 and 34). On the other hand, the trees diseased with crown-gall had slightly less vitality, since a somewhat greater number died.

A fourth experimental orchard, partly described on page 79, was planted on the Potomac Flats, near Washington, D. C., in 1907 and transplanted to the experimental farm at Arlington, Va., in 1908. Trees of the following varieties, grown in a nursery in eastern Missouri, were planted: Jonathan, Grimes, and Gano. The trees diseased with crown-gall and hairy-root were selected on account of their having intense forms of disease, in addition to possessing as abundant roots as the healthy trees. During the two years that have elapsed since planting only 8 trees have died, in spite of the fact that the tree have been twice transplanted. Out of 225 healthy trees, 3 have died of 82 trees diseased with hairy-root, 2 have died; and of 193 tree diseased with crown-gall, 3 have died, the percentage being bu slightly in favor of the healthy trees. This difference is so small a to depend entirely on chance.

The experiments mentioned, as well as observations made in othe orchards, indicate that the mere presence of the forms of crown-gal or of hairy-root at or near the crown of an apple tree, in the orchar has very little effect on the subsequent growth of the tree, provided i has a well-developed root system.

Observations made on badly diseased trees growing elsewher under poor soil conditions indicate that where either hard or soft gall extend entirely around the main root of a tree, unless it is able t throw out roots above such growths, a marked stunting effect may follow. A grafted tree of this character can not develop into a good tree unless it can form roots on the scion portion above the union.

It is inadvisable on general principles to plant any trees affected by a contagious disease like crown-gall, and particularly so with varieties that do not root well from the scion. Trees of the following varieties are more likely to overcome a mild attack of crown-gall, as they are better able to root from the scion: Ben Davis, Wolf River, Northern Spy, Grimes, Gano, Northwestern Greening, Missouri, Wealthy, Walbridge, Fameuse, and Salome.

The following statement made by Wickson (77) fully meets the views of the writer and applies to hairy-root as well as to crown-gall:

> If the diseased growth is so extensive during the early period of the life of the tree as to stunt the development of the root system, no favorable results can be expected during the later period of development of such a tree. It is fortunate that nursery trees are generally dug and sold at a period when the stunting effect of these diseases is most marked.

The same statement might be made of many poorly rooted trees which have not formed a perfect union between scion and root piece in the root graft and as a result have a defective root system, irrespective of these diseases. These constitute a considerable loss to the nurseryman where poorly fitted root grafts are used.

These statements apply to both hard and soft crown-gall and to all of the forms of hairy-root found in the nursery. The results of the investigation indicate very clearly that apple trees are able to resist the effects of these forms of disease in the orchard, and their importance has been greatly overrated.

It must not be understood, however, that trees diseased with even the milder forms of crown-gall and hairy-root are fully as valuable for planting as healthy trees. They can certainly not be rated as t grade in the markets, and if a purchaser buys trees guaranteed be free from disease and of first grade, trees with distinct forms of ease should not be supplied. Orchardists should plant healthy es and be willing to pay more for them if necessary. Since the tial cost of an orchard is only a small item in the entire outlay for maintenance, it will certainly pay to plant the best grade of trees t can be bought.

SCEPTIBILITY OF VARIETIES OF APPLE TREES TO THE DISEASE.

TA UPON A NUMBER OF COMMON VARIETIES USED IN EXPERIMENTS.

The susceptibility of the different varieties of apple trees to crown-ll and hairy-root has not been discussed by others in any previous blication on the subject. Nurserymen have asserted for a number years that certain varieties are extremely susceptible to the disease. nce the same varieties are not grown in all localities, sometimes one riety has been named as more susceptible and sometimes others. request for a list of the varieties considered to be ordinarily most dly diseased with crown-gall and hairy-root was sent to fifty of the ding nurseries in various parts of the country to ascertain if there s any uniformity of opinion in this matter. Each was requested have the field superintendent send in the names of the six worst seased varieties. In a compilation of thirty-two replies the followg varieties were found to be the most badly diseased, those named tenest being given first: Ben Davis, Early Harvest, Yellow Transrent, Wealthy, Grimes, Oldenburg, Wolf River, Red June, Gano, d Rome Beauty. All of these varieties except the last named have en included in the experiments of the Bureau of Plant Industry, om which data will be given later.

Since obtaining these opinions reports have been received for three ccessive years from twelve nurseries, the number of diseased trees ing given in the case of a large number of varieties. The reports e from nurseries in Utah, Iowa, Nebraska, Kansas, North Carolina, issouri, Illinois, Indiana, Ohio, and Virginia, and many of them were sed upon careful counts made at the time of digging. These corborate quite generally the opinions of the nursery superintendents given in the preceding paragraph. They show, however, as would e expected, a variation year by year with the same varieties in the me locality. For instance, one nursery reports for the Gano the llowing percentage of disease during successive years: 1904, 15; 905, 46; 1906, 28. Another reports as follows for the Ben Davis: 904, 15; 1905, 40; 1906, 30.

In order to obtain some idea as to whether in certain varieties there as a susceptibility to either crown-gall or hairy-root, or both, experiments with twenty-four of the more valuable commercial varieties of apple trees were conducted in connection with the other lines of investigation. The data from the trees that were grown in these experiments from ordinary whip grafts have been carefully recorded and compiled for five years. A larger number of grafts were planted and dug during the last three years than during the first two of the period of experimentation. During the first two years, 1903 and 1904, the work of experimentation was confined to one locality. During the last three years each stock of root grafts was made at a single nursery and divided into eight equal lots and planted in cooperative plats 1 to 8, thus getting the combined results of the effect of growing a variety under as many different conditions. The results from these series of experiments for five years are combined and given in Table XXI, in the appendix.

The conclusion from this series of experiments is that the different varieties of apple trees show a wide variability in their susceptibility to the disease; that some varieties are more apt to develop forms of crown-gall and others forms of hairy-root; and that none of the varieties were free from either type of the disease.

It will be noted that the varieties Wealthy, Yellow Transparent, and Wolf River developed a high percentage of crown-gall, and the Ben Davis, Wolf River, and Northern Spy varieties a high percentage of hairy-root. In both cases the forms of disease occurred chiefly on the scion portions of the trees. (See Pl. II, fig. 3.) It follows that the disease must be considered more with reference to the scion than to the seedling or root portions of the root graft; also that in root-grafted trees, susceptibility or resistance is inherent in the variety of scion, and methods for the prevention of the disease must be directed primarily to the selection of varieties resistant to the disease, and secondarily to the selection of resistant seedling stocks.

The tendency toward the development of the disease appears to be in no way related to the character of the growth of any particular variety. Certain of the varieties experimented with are vigorous growers, such as Wealthy, Walbridge, Wolf River, Minkler, Ben Davis, Northwestern Greening, Northern Spy, and Baldwin, while others, like Yellow Transparent, Whitney, Red June, Maiden Blush, and Jonathan, are much slower growers. It will be seen from Table XXVI, in the appendix, that some of the more vigorous varieties showed a high percentage of disease, as, for example, the Wolf River, with an average of 46.4; the Wealthy, with 43.3 per cent; and the Ben Davis, with 36.1 per cent. On the other hand, equally vigorous growers were the Baldwin, with only 16.6 per cent; the Minkler, with 16.8 per cent; the Walbridge, with 14.1 per cent; and the Martha, with only 10.7 per cent. It must be added, however, that there was a doubt as to whether the variety called "Martha" used in the experiment was true to name. Of the slow-growing varieties, the Yellow Transparent showed an average of 34 per cent of diseased trees, the Maiden Blush 26.4 per cent, and the Whitney 20.4 per cent. It must be concluded that susceptibility is not directly related to vigor of growth.

It was found that those varieties that throw out roots more readily from the scion are the ones that are most susceptible to hairy-root. The forms of hairy-root apparently originate only in tissue centers capable of producing adventitious roots.

SUSCEPTIBILITY OF SCIONS GROWN IN DIFFERENT LOCALITIES.

The collection of data on the susceptibility of different varieties of apple trees to crown-gall and hairy-root brought out the fact that while certain varieties were found to be more susceptible than others, the same variety during the same season or several seasons was diseased more in one locality than in others. This could probably be due to a number of facts, one of which might be a varying susceptibility in stocks of the same variety grown in different localities.

To ascertain whether there was any difference in susceptibility of stocks in different sections of the country, scions of three different varieties of trees were obtained from a number of nurseries from Ohio to California. These varieties were Wealthy, Wolf River, and Yellow Transparent. Each variety was made into root grafts, the same stock of seedlings being used. They were planted in 1906, each variety in a different plat, and grown three years before digging. The names of the nurseries furnishing the scions are not given, numbers being substituted, but the State in which each nursery is located is given. Table XXII, in the appendix, gives the number of trees grown from each lot and the percentage diseased.

From the results given in the table it will be seen that there was a great variation in the amount of disease present in scions taken from different localities, but it will not be safe to ascribe this wholly to greater susceptibility, since the health of the trees from which the scions were selected in each locality could not be ascertained, and it has already been shown that this is a factor in the problem.

The difference in the percentage of disease in the case of the Wolf River variety, as shown by the two extremes in the results from the experiment, is 14.7 per cent. In the experiment with the Wealthy it is 17.5 per cent, and with the Yellow Transparent 12.8 per cent. This is quite a wide range, but since the results can not be considered as strictly comparative they may be taken as tentative, paving the way for further inquiry along this line.

COMMUNICABILITY OF THE DISEASE IN THE NURSERY AND THE ORCHARD.

PREVIOUS PUBLICATIONS ON THE COMMUNICABILITY OF APPLE CROWN-GALL.

Ever since crown-gall and hairy-root have been brought to the attention of plant pathologists one of the chief problems under discussion was related to the question of whether these forms of disease are communicable, especially under nursery and orchard conditions. As a matter of precaution, growers have been generally advised to refrain from planting diseased trees, and their destruction, both in the nursery and the orchard, has been recommended. In some cases trees to the extent of a carload at a time have been condemned by zealous nursery inspectors and destroyed on account of the presence of diseased trees.[a]

The earlier accounts of the disease by W. E. Smith (56), Yates (80), Bailey (5), and others, are based upon the idea that the disease is probably not communicable, but later researches have overthrown this theory.

Woodworth (78) recommends rejecting all affected stock, purchasing from nurseries known to be entierely free from crown-gall, burning diseased trees, and devoting fields in which the galls have appeared to some other crop for a number of years.

Toumey (68), in his work on the crown-gall of the almond, records an experiment in which he attempted to transfer the disease from the almond to the apple, both by soil inoculation and by graft insertion, but was unable to communicate the disease.[b]

Selby (52) recommends the destruction of all affected stock, and says:

> Soil which causes this sort of growth upon peach trees in the nursery has been known to produce the same upon the apple, and conversely.

Garman (15) makes the following statement, without citing proofs:

> It has been demonstrated that crown-gall is a contagious disease, to be conveyed to seedling trees by crushing the galls and putting them in soil in which seeds are planted. Trees grown with others that are galled are therefore not above suspicion, even when they show no outward evidence of the disease.

Guilford (17), speaking of apple crown-gall, says:

> For the past three years I have been trying to inoculate the Virginia crab roots with this gall. Conditions were made favorable by wounding the roots and covering them

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[a] Paddock, Wendell. Crown-gall. Bulletin 86, Colorado Agricultural Experiment Station, 1903, p. 5.

[b] Dr. Erwin F. Smith has shown the writer large, hard crown-galls on apple stems produced by him in 1908 by pure-culture inoculations of *Bacterium tumefaciens* obtained from the soft crown-gall of the peach.

> with galls. I have failed to get a catch; but I have no trouble in making the inoculation on our common seedlings. They usually take hold on the seedlings at the graft union.

This would seem to indicate immunity of the Virginia crab.

Howard (24) made a number of experiments to test the contagious nature of different galls, using apple grafts, and found that apple trees inoculated with apple galls were affected to the extent of 30 per cent; apple trees inoculated with raspberry galls, 16⅔ per cent; and apple trees inoculated with peach galls, 22 per cent. He, however, gives no comparative results with apple trees which had not been inoculated; hence, it is not certain that his results are due to inoculation.

Alwood (2) states:

> Apparently crown-gall can be readily inoculated from a diseased plant into healthy ones; hence, diseased plants should not be allowed to remain among healthy ones in the orchard.

In another publication Alwood says:

> Cultivating the orchard may possibly serve to spread the disease by carrying disease germs from one tree to another. It is very probable that infection occurs without assistance wherever parts of the diseased tissues remain in the ground occupied by apple trees.

Alwood bases his conclusions in the first instance upon experiments containing a small number of trees.

Norton (37) regards crown-gall as a communicable disease on the apple, and says that "in grafting, the disease may be communicated from diseased to healthy trees by means of knives, etc." He does not, however, give experiments or cite authority for the statement.

Butz (7) states that healthy trees set in infected land develop the disease within a year or more.

The author (19) stated in a bulletin in 1905, concerning the hard form of crown-gall on apple trees, that "the results of extensive inoculations with this type have failed to prove that this disease is of a contagious nature." And again, concerning the soft form of crown-gall: "Nor is there proof yet that they are of a contagious nature." Similar statements were published in 1905 in Science (18) and in the National Nurseryman (18). These opinions were based upon a failure to secure positive results from inoculations of apple trees with pieces of hard galls in earlier experiments, disease occurring both in control and in inoculated plants.

Later experiments by the author (22) in 1906 and 1907 and published in 1908 established the fact that crown-gall of the soft form on apple trees was contagious and that it was identical with crown-gall of the almond, apricot, blackberry, cherry, peach, plum, prune, chestnut, and walnut. These experiments also indicated that the disease in the hard form was either slightly or not at all contagious.

From the preceding citations, which are representative, it is apparent that the opinions of plant pathologists, with few exceptions, have been as follows:

(1) Apple crown-gall spreads rapidly in the nursery and the orchard from tree to tree.

(2) It may be communicated from diseased to healthy trees by contact, in bundles, etc.

A review of the literature on the subject reveals that little has been done previously in the way of experimentation to substantiate these views as to the degree and the rapidity of the spread of the disease in the nursery and the orchard.

PREVIOUS PUBLICATIONS ON THE COMMUNICABILITY OF HAIRY-ROOT.

The previous citations bore upon the communicability of crown-gall, but in most cases the statements made no separation of crown-gall from hairy-root, both types of disease being included under the term "crown-gall."

Stewart, Rolfs, and Hall (64), who first described hairy-root of the apple, did not express their opinion as to the communicability of the disease, but regarded it as separate and distinct from crown-gall.

EXPERIMENTS ON THE COMMUNICABILITY OF THE DISEASE.

Studies on the formation of callus as related to crown-gall.—In order to study the relation of callus to wounds an experiment was prepared with a number of sets of apple cuttings, seedlings, and root grafts. Some of the cuttings were made with blunt or square ends, others with slanting or pointed ends. Some were cut with longitudinal incisions, some with spiral incisions, and some with cross incisions through the bark and cambial layer; others lacked such incisions. The seedlings were washed clean, sterilized for five minutes in a one-tenth per cent water solution of corrosive sublimate, and again washed in boiled water. They were cut off at both ends, roots and shoots, to the length of 9 inches. The root grafts were made of the tongue or whip-graft pattern, some closely fitted, some poorly fitted, others with the upper end of the root cut off bluntly, and others with the lower end of the scion cut off in the same manner.

The materials were prepared for the experiment the 1st of February, the usual time for root grafting at the larger nurseries in the Mississippi Valley. The cuttings, seedlings, and root grafts of each pattern were tied for storage in bundles in the same manner as root grafts are tied for storage at nurseries. They were divided into two equal series, one of which was stored in a cool cellar at a temperature of 50° to 60° F. and the other in a greenhouse at a temperature of 65° to 90° F.

Both series were packed in sterilized jars in a number of different kinds of packing. The jars and substances used in packing were sterilized in an autoclave at a temperature of 239° F. for three hours. The sets were placed under the following conditions of moisture in the cellar and the greenhouse: (1) Moist sphagnum moss; (2) moist sand; (3) moist sawdust; (4) moist soil; (5) moist chopped excelsior; (6) moist air over water, surrounded by wet blotting paper; (7) all but the tips of the upper ends in water.

In nursery practice root grafts are made and either planted out immediately or stored in moist conditions until the wounds are filled with callus. Of the two sets of root grafts in the experiment those placed under the cooler conditions formed callus about one-half as rapidly as those in the warmer conditions. Those in the warmer conditions, had they been in the nursery, should either have been planted at the end of ten to fourteen days or placed in cold storage to inhibit further development of callus. Those in cooler conditions were ready to plant in three to four weeks, and at the end of six weeks the formation of callus had become excessive, especially in moist moss, earth, sawdust, and chopped excelsior. Sand was found to be much the best for packing root grafts, since only a moderate formation of callus took place. In this substance there was no excessive formation of callus except in a few cases when the period of time in the cellar was extended to two months. The grafts, however, after two months in the cellar or one month on the benches had begun to form shoots and roots, and for this reason were not in good condition for planting.

The experiment gave the following general results:

(1) On apple cuttings callus formed readily but not excessively in spiral and cross incisions, and less readily in longitudinal incisions, filling the cuts with new tissue, and in the former often projecting from the surfaces in small outgrowths.

(2) Usually no callus developed from the upper cut of cuttings, seedlings, and scions, whether cut off slanting or square. If any was formed, it barely showed above the surface of the cambial layer.

(3) Under moist air conditions, either in moss, sand, sawdust, soil, or in the open air, callus formed readily on the lower cut ends of cuttings, seedlings, and scions. In time it formed excessively developing outgrowths half an inch or even more in diameter.

(4) In root grafts in time callus formed excessively under the conditions mentioned in the preceding paragraph at the lower pointed end of all the scions and at the lower cut ends of some of the roots in the grafts (Pl. VIII, fig. 2). The graft union was closed with callus

in a short time, but, except as mentioned, the callus was usually confined to the wounds and did not project beyond.

(5) Under very wet conditions, as in water, the formation of callus was almost entirely inhibited in wounds, but lenticellular proliferations were abundant from other parts of the surface of shoots and roots.

(6) The two regions where the formation of callus in root grafts was most abundant, the lower point of the scion piece and the lower end of the root piece coincide exactly with the position of more than 90 per cent of the galls occurring on root-grafted trees, indicating a close relation between the formation of callus and the development of the disease.

Fifty root grafts with large outgrowths of callus (Pl. VIII, fig. 2) were selected from those in the experiment and the same number with no excessive development of callus were selected. These were planted in separate benches in a greenhouse in ordinary soil, not sterilized. They all grew. Of the set with excessive callus 32.2 per cent developed galls of the hard form. All of the other set grew into healthy trees. This indicates that excessive callus formation either is incipient crown-gall or may develop into it. Storage conditions should be such as to hinder the excessive development of callus. Moist sand is the best medium of those tested for packing root grafts.

Studies on root formation as related to hairy-root.—In connection with the study of the formation of callus and under the same conditions, an experiment was conducted for the study of root production on healthy seedlings as compared with that on those diseased with hairy-root and the woolly aphis. Seedlings of these three types were prepared as in the former experiment and placed under the same conconditions of moisture.

It was found that as a rule no roots were produced from cuttings or scions from the limbs of healthy apple trees under the conditions of the experiment. Such was not the case with cuttings taken from the tops of a number of apple seedlings badly diseased with the simple form of hairy-root. Roots were produced freely from all of these under moist conditions. Where healthy apple seedlings in which the stem and root tip had not been cut off were kept in a cool condition for two months and in a warm condition for one month, a few scattered new side roots developed on most of the roots, but only shoots or leaves developed from the stems. In the case of the seedlings diseased with hairy-root which were placed under similar conditions, abundant root formation, usually in clusters or tufts, took place from tissues in or adjacent to the diseased parts, not only from the roots but often from the stems, and at the same time shoots were thrown out from the root tips below diseased areas. This is a reversal of the natural order of root and shoot formation in apple seedlings.

A third set of apple seedlings was also placed at the same time under the conditions of the experiment. This consisted of a number of bunches of apple trees badly affected with aphis galls but showing no hairy-root formation. It was thought that these seedlings with galls might develop hairy-root, but they behaved in their rooting no different from the set of healthy seedlings.

The relation existing between the woolly aphis, however, and the aerial form (stem tumors) of hairy-root (Pl. V, fig. 2) is a subject for future investigation. The following observation gives the reason: In a seedling nursery in Indiana, mentioned on page 37, about forty trees were found diseased with this form of hairy-root, and they were also infested with the woolly aphis. It was noted that the trees adjacent to the badly affected trees were contracting the disease, indicating that this aphis may assist in the spread of the disease by carrying the organism causing it.

No communication of the disease to healthy uninjured seedlings.—In an experiment with healthy apple seedlings, described on page 16, it was shown that healthy seedlings, uninjured as far as could be determined, failed to become diseased even when the soil about their roots was mixed with finely chopped pieces of living soft and hard crown-galls from apple trees. Thus, without wounds, there was no communication of these forms of disease to apple seedlings. Where wounds were made, other conditions being the same as before mentioned, 4 per cent of the trees became diseased with the hard form of crown-gall.

The disease is communicable to wounded seedlings.—A number of experiments have been conducted with healthy apple seedlings grown in the nursery and carefully washed and the tips of the roots cut off. They were then divided into lots of approximately equal numbers and prepared for the experiment as follows: The plants in one lot were prepared for a control by making a slanting incision into the root and then wrapping the wound with a thread in the same manner that grafts were wrapped. A second control set was similarly treated, except that a cross section of clean, healthy apple roots was inserted in the wound before wrapping. A third set was prepared like the first, except that a piece from the outside of a living apple crown-gall of the soft form was inserted in the wound. A fourth set was prepared similarly, except that a piece from the outside of a living apple crown-gall of the hard form was inserted. A fifth set, consisting of a smaller number of seedlings, was similarly prepared, except that a cross section of a piece of living apple seedling diseased with the simple form of hairy-root was inserted. After growing one season the results were as given in Table XXIII, in the appendix.

These experiments prove that soft crown-gall of the apple is communicable to some extent in wounds by inoculating with pieces of living galls, but that pieces of hard crown-galls and the simple hairy-root may not readily communicate the disease under similar conditions.

Increase of the disease in root-grafted trees due to the inoculation of grafts.—In order to test the communicability of the soft form of apple crown-gall, a set of nursery experiments was conducted. The grafts were prepared from healthy scions from the varieties Red June, Rambo, York Imperial, and Minkler, grafted on the roots of healthy selected seedlings from trees grown from the same seed in the same field. The grafts were prepared in three lots: The first as ordinary tongue or whip grafts; the second lot had a piece of clean cross section of healthy apple seedling root inserted beneath the lower end or tongue of the scion before wrapping each graft; the third had a piece of living apple crown-gall of the soft form taken from the outside of the gall and inserted under the lower end of the scion in each graft before wrapping it. Each of the three lots of grafts was separated into eight equal sets, which were planted and grown in three experiments (1, 2, and 3) in the same localities and which were dug in the same manner as the grafts in the experiments whose results are given on page 62. The results of the experiment are given in Table XXIV, in the appendix.

Briefly summarized, the results from the experiments are as follows: Where a piece of living healthy root chip had been inserted in the graft union it caused an increase of crown-gall amounting to from 1 to 14.2 per cent and where a piece of living apple crown-gall had been inserted there was an increase of crown-gall amounting to from 2 to 33.8 per cent as compared with the amount of crown-gall present in trees grown under similar conditions from ordinary root grafts. In the former case the average increase was 4.7 per cent and in the latter 12.6 per cent. The resulting disturbance did not vary the amount of hairy-root present in either case.

On the whole, this set of experiments shows that crown-gall is communicable in root grafts if they have an opportunity to become infected at the time the healing processes are taking place in the union; or, in other words, at the time callus is formed abundantly in the wounds.

The data in experiment 1 indicate not only that there is no further spread of crown-gall in the nursery rows the second and third years, but that there is an actual decrease of the disease due to the recovery of many trees. This must have taken place, since in experiment 1 every third tree was dug with spades the first year, the second year one-half of those remaining also with spades, and the balance of the trees the third year, with a tree digger. In digging the trees with spades those remaining were often wounded, and this alone should have led to an increase of disease. In this and in all of the other experiments mentioned in this bulletin conducted by the author he personally examined the root grafts when made, directed the planting and cultivation, saw every tree as it was dug, and noted in each case the condition of the roots.

Increase of the disease due to poorly fitted root grafts.—In order to determine the relation of defective grafting to the increase of crown-gall in the nursery a number of experiments were conducted. Two series of whip or tongue root grafts were prepared from the same lots of scions and seedling roots. The varieties Gano, Wealthy, Red June, Martha, and Whitney were used. The root grafts of one series were carefully made, root and scion pieces of equal diameter being selected and smoothly fitted at the union (Pl. IX, fig. 2, *A*). The second series consisted of similar grafts very poorly fitted in which either root and scion piece were of different diameters or the end of the one projected beyond the surface of the other (Pl. IX, fig. 2, *C* and *D*).

These root grafts were planted in eight equal lots in experiments 1, 2, and 3 in cooperative plats 1 to 8 (for description see p. 78). In experiment 1, four lots of grafts planted in cooperative plats 1 to 4, every third tree was dug at the end of one season, every second at the end of two years, and the remaining trees at the end of the third year. In experiment 2, two lots planted in cooperative plats 5 and 6, every other tree was dug at the end of the first season, and the remaining trees at the end of the second year. In experiment 3, two lots planted in cooperative plats 7 and 8, all of the trees were dug at the age of 2 years. Table XXV, in the appendix, gives the results from each of the experiments.

A smaller experiment, similarly prepared, in which a number of poorly fitted root grafts and twice as many carefully fitted grafts from the same stock of scions and seedlings were made, was conducted in eastern Missouri. The results of the experiment are as follows: Out of a total of 357 trees grown from the smoothly fitted root grafts, 7.8 per cent was diseased with crown-gall and 5.1 per cent with hairy-root; and out of a total of 217 trees grown from the poorly fitted root grafts, 17.5 per cent was diseased with crown-gall and 11.1 per cent with hairy-root, or a saving of 15.7 per cent on trees of a marketable size due to smooth fitting.

Briefly summarized, the results of these experiments are as follows:

(1) Poorly fitted root grafts, as compared with carefully fitted ones, yielded an increased percentage of diseased trees both with crown-gall and with hairy-root. The increase of crown-gall in both

experiments varied from 1.2 to 41.7 per cent and of hairy-root from 1.8 to 6 per cent.

(2) The use of carefully fitted root grafts, as compared to poorly fitted ones in both experiments, yielded an increased stand of trees. This increase amounted to 21.6 per cent in the first experiment and to 26.7 per cent in the second experiment. This was due to the death of many more of the poorly fitted grafts just after planting, before they struck roots.

In the case of the smoothly fitted grafts the superior stand of trees is due to the more perfect union formed by the callus quickly establishing a circulation in the graft when it is planted in moist soil. This brings about a more rapid healing and results in a higher vitality and an increased stand of trees.

A poor fitting of root grafts also causes an increase of abnormal callus, permitting a greater communicability of crown-gall during the first year's growth. This increase takes place chiefly at the time the wounds of the graft union are healing. The same does not apply so well to forms of hairy-root, which, as a rule, are not necessarily connected with the graft union, but occur as often on other portions of the roots of grafted trees.

What does this loss from poorly fitted root grafts mean to the nurseryman? On the basis of 15,000 trees to the acre, a low estimate, it means the loss of 2,355 marketable trees for every acre of apple trees. If trees are valued at 8 cents apiece, it means the loss of $188.40 per acre.

The use of scions from diseased trees increases the amount of disease.—It has been the custom of some growers of grafted apple trees in the central United States to grow their stock three years before marketing it. The yearling trees are cut back to near the ground, and the tops are used for scions in making root grafts for the next season's planting. A portion of such scions must, of course, come from trees with diseased roots. Some growers cut scions directly from cull trees in the nursery bins, many of which are diseased with crown-gall and hairy-root. Others plant these culls in their scion orchards and later cut scions from them. These three methods of selecting scions must be condemned, since they tend to increase the number of diseased trees grown from orchard grafts.

In order to test the effect of taking scions from trees with diseased roots, a series of experiments has been conducted, in which scions were taken from trees with both healthy and diseased roots.

The grafts in the first and largest experiment were planted in 1905. The trees were dug in 1906, at the age of 2 years. In this experiment the trees used were grown from root grafts made in equal number from scions taken from healthy trees and from those diseased with crown-gall. The varieties used were Collins, Wealthy, York Imperial, Gano, and Jonathan, planted and grown in independent plat 2 (see p. 78). The results from this experiment are given in Table XXVI, in the appendix.

The second experiment, in which the trees were dug in 1907, at the age of 1 year, was made in independent plat 3 (see p. 78). The root grafts were made with scions from both healthy trees and those diseased with crown-gall and hairy-root. The results are given in Tables XXVII and XXVIII.

The grafts of the last experiment were planted on the clayey soil in independent plat 4 (see p. 78). The sets of root grafts were made from scions taken from healthy trees and from those diseased with crown-gall and hairy-root. The results of this experiment are given in Tables XXIX and XXX.

These experiments show a decided increase of disease in root-grafted trees grown from grafts made from scions from apple trees diseased with crown-gall and hairy-root as compared with those grown from scions selected from healthy trees. This increase in the different experiments is as follows:

An increase of crown-gall in the first experiment of 2.2 per cent, in the second of 7.4 per cent, and in the third of 7.2 per cent. An increase of hairy-root in the first experiment of 7.1 per cent, in the second of 12.5 per cent, and in the third of 16.3 per cent.

Although this increase is not very great, it is cumulative where the process is repeated year after year, and is of sufficient importance to deserve the careful attention of every nurseryman. All scions should be selected from healthy trees, and the same observation will no doubt apply to the selection of buds for budding where the twigs are kept dormant in cold storage. To accomplish this means that the scion orchard must be grown from healthy trees, and all diseased trees should be removed from the scion orchard as soon as detected.

The spread of the disease from tree to tree in nursery rows is almost negligible after the first year.—In experimenting along the various lines of the problem, a number of experiments were conducted so that all conditions would be equalized as nearly as possible, and a definite proportion of the trees grown in nursery rows was dug each year for the purpose of noting the spread of the disease in the rows from tree to tree. Three sets of such experiments, designated as experimental sets 1, 2, and 3, were conducted in cooperative plats 1 to 6.

In experimental set 1 seven duplicate experiments, each using grafts from the same stocks of healthy scions and seedling roots, were planted in four equal lots in cooperative plats 1 to 4. One-third of the trees grown from these root grafts were dug at the end of one year, digging every third tree; one-half of the remainder, or each alternate tree, were dug at the end of the second year, and the remaining trees were dug the third year. The combined results from these experiments are given in Table XXXI, in the appendix.

In experimental set 2 the conditions in set 1 were duplicated and the grafts planted in cooperative plat 6 in 1905. One-third of the trees, as before, were dug at the end of the first year, but at the end of the second year it became necessary to dig the remainder on account of the more rapid growth of the trees in this locality. The results from this experiment are given in Table XXXII.

In experimental set 3 the conditions of set 1 were duplicated and the grafts planted in cooperative plat 5 in 1905. One-half of the trees, selecting each alternate tree in the row, were dug at the age of 2 years and the remainder at the age of 3 years. The results from this experiment are given in Table XXXIII.

The results from the three sets of experiments are summarized as follows:

(1) They show a decrease of crown-gall in trees in nursery rows after the first year; in set 1 a decrease from 26.7 per cent the first year to 9.1 per cent the second and to 4.7 per cent the third; in set 2 from 20 per cent the first year to 12.8 per cent the second; in set 3 from 11.7 per cent the second year to 2.6 per cent the third.

(2) They show a general and decided increase of hairy-root the second year, with a slight or no increase the third. In set 1 there was an increase from 5.5 per cent the first year to 8.6 per cent the second and 8.7 per cent the third; in set 2 from 7.9 per cent the first year to 10.3 per cent the second; in set 3 from 6.4 per cent the second to 10.2 per cent the third year.

(3) The increase in hairy-root does not nearly offset the decrease in crown-gall and some of the trees must throw off the disease and recover. In set 1 crown-gall decreased 22 per cent, while hairy-root increased but 3.2 per cent. In other words, the number of diseased trees decreased 18.8 per cent. In set 2 crown-gall decreased 7.2 per cent, while hairy-root increased 2.4 per cent, and of diseased trees there was 3.8 per cent less. In set 2 the percentage of crown-gall decreased 9.1, while that of hairy root increased 3.8, and of diseased trees there was a decrease of 5.3 per cent.

In conclusion, the time when the disease is communicated to the trees is during the first year. In the light of experiments already described the communicable period must be during the time of the formation of callus for closing the wounds in the union of scion and root.

These experiments show that crown-gall as a rule does not spread from tree to tree in the nursery after the first year and that hairy-root increases considerably from the first to the second year, and but slightly the third year.

The disappearance of crown-gall is considered to be due to two causes: (1) Some of the hard galls throw out roots and develop into woolly-knot, while (2) a much larger number of galls gradually disappear as the tree increases in size, and such trees must recover from the disease.

In closing the discussion of this subject it should be noted that the results given here are from seven parallel sets of experiments in six localities, or forty-two parallel experiments in five States, and include data on 31,886 trees. The results might not have been the same in all localities in the United States, but certainly fairly represent typical nursery conditions in the heart of the apple-growing belt in the central States of the Mississippi Valley.

Pruning and grafting knives are not responsible for much of the disease.—In view of the fact that it has been asserted that crown-gall is largely communicated by the use of pruning and grafting knives, 100 carefully selected seedlings from the nursery were washed, thoroughly dried, and planted in sterilized soil in a greenhouse (p. 77). Before being planted a downward cut on the root near the ground line was made with a grafting knife which had in each instance just been used in making a cut in a live soft apple gall. The greatest care was exercised to see that the knife used in making the cuts in the seedlings was in each case passed back and forth through a fresh crown-gall before the cut was made. For comparison, 100 healthy seedlings from the same stock were planted after being carefully washed and dried. Before planting, a cut was made in each of these seedlings as before, except that in each instance the knife blade was dipped in a one-tenth per cent corrosive-sublimate solution before making the cut. At the end of the growing season 4 per cent of the control seedlings had developed crown-gall and only 2 per cent of those that had been wounded with the gall-infected knife were similarly diseased. This experiment fails to confirm the belief that the grafting knife is responsible for much of the crown-gall present in root-grafted stock in the nursery.

Crown-gall not readily communicated to dormant trees stored in bundles.—The communicability of crown-gall by contact of healthy trees with diseased ones while tied in the same bundle has been the subject of much dispute, especially between nurserymen and nursery inspectors.

The experiments conducted in cooperative plat 6 in 1905 may throw some light on this subject. Two sets of seedling apple trees, 100 in each, were inoculated with chips of living soft galls from apple trees inserted into slanting incisions in the roots and tied with grafting thread. One set was prepared about six weeks before planting and kept dormant by being stored in moist excelsior in a cool place; the other was prepared in the same way as the first and planted out immediately. For each set an additional set of an equal number was wounded and wrapped with thread without inoculating. All were grown one year. Of the inoculated stored seedlings, 7.4 per cent became diseased with crown-gall; of the control, 4.3 per cent, chiefly of the hard form; of the inoculated set planted immediately, 34.1 per cent became diseased with crown-gall, chiefly of the soft form; and of the control, 2.9 per cent, chiefly of the hard form.

In a second experiment, 500 root grafts were prepared from healthy scions of Wealthy grafted healthy seedling roots as a control set. A similar set of 500 grafts was prepared by rubbing the tongued end of both the scion and the root pieces on the freshly cut surface of a living soft gall from an apple tree before joining together the cut, a number of galls being used. These were planted in the nursery after being stored for six weeks in separate boxes in a cool cellar. At the end of one season's growth there was approximately the same amount of disease in the control as in the inoculated sets, the control containing about 19.5 per cent of trees diseased with crown-gall, and, the inoculated set 21 per cent, both chiefly of the hard form.

The results of the these experiments indicate that the communication of crown-gall to wounds in apple trees is a variable factor and that the contact of wounded living galls with wounded surfaces when dormant may result in little or no infection, but that under growing conditions, where callus is formed abundantly, such as resulted at once where the seedlings were inoculated with pieces of living apple galls and planted immediately, the disease was communicated readily. In these seedlings growth, with the formation of callus, took place at once, favoring the entrance of the organism. In the case of the stored seedlings and grafts, owing to the low temperature, the formation of callus was retarded at least one month before it became warm enough for its development.

In the writer's opinion, given in the light of the results of these and other experiments recorded in this bulletin, crown-gall is communicable by contact only in wounds where fresh callus is being formed. Where trees are dormant there is little danger of communication.

The disease only slightly communicable in orchards.—Reference will again be made to orchards 1 and 2, already described. A statement of the condition of the trees in these orchards at the beginning of the experiment and six years later, when the trees were dug, is given in Tables XXXIV and XXXV, in the appendix.

The results from the experiments, as shown in Tables XXXIV and XXXV, are as follows: The orchards were planted with trees 50.1 per cent of which were diseased with crown-gall. At the close of six years 40.5 per cent of the original number of trees was diseased, of which 15.8 per cent was diseased with crown-gall and 24.7 per cent with hairy-root.

Of 416 trees alive at the end of six years, 226, or 54.3 per cent, were healthy, as compared with 49.9 per cent of the original number.

In order to further analyze the results of the experiment, Tables XXXVI and XXXVII are given, with the separate record of the healthy and diseased trees in each plat.

From these tables it will be seen that, after deducting the dead trees, 1 out of the 83 healthy ones in orchard 1 had become diseased with crown-gall and 18 with hairy-root; and out of the 70 healthy trees in orchard 2, 10 had become diseased with crown-gall and 29 with hairy-root; but it was noted at the time of digging that in every case the amount of disease on the newly infected trees was slight, the badly diseased trees in the plat after six years being few in number and among those that were originally diseased. In comparison with this increase of disease it must be noted that, after deducting the number of dead trees, out of 96 diseased trees planted in orchard 1, 32 fully recovered and out of 139 diseased trees planted in orchard 2, 41 recovered entirely. In other words, where 58 trees became slightly diseased, 11 with crown-gall and 47 with hairy-root, 73 trees recovered from crown-gall during the same period without any treatment whatever.

This slight communicability shown by traces of disease is certainly almost negligible from the standpoint of the orchardist and must have occurred during the first growing season, since great care was taken not to wound the trees by cultivation. The experiment certainly indicates that apple trees when they are once established are not in danger of becoming seriously diseased on the roots if cultivated carefully and without incurring wounds, even when every tree 9 feet away in the adjacent rows is diseased, as in the experiment. There appears, then, no need of removing diseased trees from orchards, except when they are not doing well; that is, when they show every indication of becoming unprofitable or when there is danger of communicating the disease to valuable small fruits. The matter of communicability as it applies to other apple trees in the orchard need hardly he considered when the question of removal is being taken into account.

PREVENTION AND CURE.

PROBABLE FUTILITY OF ATTEMPTS AT PREVENTION.

Numerous recommendations have been made from time to time by plant pathologists and others looking toward the prevention of crown-gall by the removal of supposed sources of infection. These recommendations were made not specifically for the apple disease but for crown-gall in general. Advice has generally been given to obtain nursery trees as far as possible from nurseries free from disease. It has generally been considered that the planting of trees affected with crown-gall and hairy-root is liable to give rise to diseased trees throughout the orchard. In spite of the most vigorous nursery inspection for a number of years in many States the disease on apple trees is quite generally disseminated throughout the United States, and the writer knows of no apple-growing nursery that is entirely free from the forms of disease described in this bulletin.

Although much advice has been given for the prevention of the disease, little in the way of successful experimentation along this line has been done hitherto. Butz (7) planted healthy trees in infected land to which finely powdered sulphate of copper had been added. On account of the death of most of the trees, attributed to a serious drought, he was unable to make any generalization regarding the efficiency of this treatment. Sulphur used by him in the same way had no effect in retarding the disease.

Popenoe (45), in speaking of attempts made by growers in Kansas to prevent loss by apple crown-gall, says:

> It has been the hope of some nurserymen to prevent the large percentage of loss from diseased stock by planting their apple grafts in localities and soil not before in apple trees, but in some notable cases coming under my observation within the last few years this endeavor has failed signally of the object.

The writer personally knows of similar experiences by nurserymen in a number of localities in Kansas, Nebraska, Missouri, and Iowa.

The writer has conducted a number of experiments along the line of prevention and cure. Some of these have resulted in materially lessening the amount of disease present in nursery stock. The results will be given, in the hope that they will effect a great saving not only to nurseymen but to orchardists as well.

As a result of many observations in nearly three-fourths of the States in the Union the writer is of the opinion that the crown-gall organism is so widely disseminated that any system of eradication must fail.

In discussing methods to control and limit the formation of crown-gall and hairy-root on apple trees in nurseries and orchards, the the subject-matter will be brought under two general headings, one ealing with methods for the control of the disease in the nursery, nd the other with methods for its control in the orchard.

METHODS FOR THE CONTROL OF THE DISEASE IN NURSERY BINS.

Since it has been found that apple crown-gall is communicable, and an be transferred from the apple to the stone fruits, the raspberry, he blackberry, the rose, the grape, etc., and vice versa, nurserymen hould at the time of digging pick out and remove all plants diseased with crown-gall. They should not be tied in bundles with other plants, owing to the slight possibility of transferring the disease to healthy wounded plants. In the case of apple-root grafts it has been shown that they are most susceptible at the time the graft is forming callus and is uniting. Care should be taken to keep the nursery bins, especially where material for root grafts is kept, free from diseased plants. It is best to clean all nursery bins and thoroughly spray them with a strong solution of copper sulphate each year before the time for storing trees for the winter.

PROPAGATION OF SUSCEPTIBLE VARIETIES OF APPLE TREES BY BUDDING.

It has been shown elsewhere in this bulletin that in most sections of the country where apple trees are propagated, both by budding and by root grafting, budded trees are freest from disease. For this reason it is advisable to propagate those trees most subject to crown-gall and woolly-knot by budding. There is an objection offered to budding on account of the necessity for growing the trees a year longer. The additional cost for this extra year may be more than offset by the increased number of healthy trees obtained by this method. The additional loss from woolly aphis during the last year of growth in the nursery is asserted by many nurserymen to be so great in some localities as to preclude budding. If such nurserymen will consult with the Bureau of Entomology of this Department as to the proper method of combating and controlling this troublesome insect pest by fumigation, etc., means will be found by which this loss may be greatly diminished, and propagation by budding in the case of varieties susceptible to crown-gall will become profitable.

IMPROVEMENT IN METHODS OF ROOT GRAFTING.

SELECTION OF HEALTHY SCIONS NECESSARY.

In the control of any disease that might be transmitted through root grafts it is perfectly logical to demand that the pieces, both scion and root, that are built into the root grafts should be healthy. It has been shown on page 23 that there is an increase in disease due to taking apparently healthy scions from trees whose roots are diseased. Growers of root-grafted trees will make no mistake if they insist on getting scions from strictly healthy trees, and they should grow their own healthy scions if possible.

SELECTION OF HEALTHY SEEDLING ROOTS NECESSARY.

The selection of healthy seedling trees from which roots are to be taken for root grafts is of prime importance to the grower. It has already been shown by experiment that the selection of roots from seedling trees diseased with hairy-root often results in the growth of a tree with diseased and deformed roots (Pl. VII, figs. 3 and 4), one which is unmarketable, even though in many cases it would no doubt develop into a profitable tree in the orchard. It is not profitable to grow diseased trees or to be the distributor of diseased stock.

It has also been shown by experiment that it is not best to use the apparently healthy portion of a seedling root which bears a soft gall. The use of such stock will certainly result in an increase of this form of disease and can not be profitable.

Finally, it must be said to growers of seedling apple trees that when the seedlings are dug, all rough, warty, hairy, or tufted seedlings should be rejected and destroyed (Pl. III, fig. 1, and Pl. IX, fig. 2, *G* and *H*). As a matter of precaution, they should not be tied up with healthy seedlings. Nurserymen purchasing seedlings for making root grafts should insist on this.

CAREFUL FITTING OF ROOT GRAFTS NECESSARY.

The influence of a projecting scion in the formation of excessive callus and the liability of such callus through infection to develop into crown-gall has already been discussed. It will pay nurserymen to put a premium on neat, close-fitting tongue grafts made at a reasonably rapid rate rather than to encourage the rapid manufacture of a poorly-fitted graft with the scion projecting at the union or with one made too blunt at the lower end, such as are shown in Plate IX, figure 2, *C* and *D*. The best results with the least amount of disease will be secured by the use of No. 1 unbranched seedling roots upon which there have been closely and smoothly fitted scions of equal diameter, properly wrapped. The stress of competition in recent years has led to increased carelessness in the manner in which root grafts have been put together and to the use too often of inferior roots and scions.

EXPERIMENTS ON THE BEST METHODS OF WRAPPING ROOT GRAFTS.

Mention has been made of the tendency of root grafts to form excessive callus at the lower tip of the scion when stored under moist conditions in sawdust, excelsior, moss, and other similar materials. Where the two pieces of the graft are snugly fitted, there is little endency for the callus to form anywhere except in the intervening paces. When the pieces are more or less imperfectly fitted and are ot firmly held together, especially at the lower end of the scion, there s a tendency for the callus to grow out into the air, forming thick ushions (Pl. VIII, fig. 2) or gall-like outgrowths. The wrappings vere planned to confine this formation of callous and to hasten the nion between scion and root pieces.

In order to find a method of controlling the formation of callus, 5,200 root grafts were wrapped with various materials (Pl. VIII, ig. 1) during the winter of 1904–5. The idea of wrapping root rafts is not a new one, since nurserymen used both waxed cloth and vaxed paper for many years before the present method of thread vrapping came into vogue.

All of the grafts made for the experiment were of the type known s "whip" or "tongue" grafts. They were especially well made rom No. 1 Kansas roots, fitted with a selected lot of scions from ach of the following varieties: Winesap, York Imperial, Wealthy, Missouri, and Northern Spy. They were made in February, packed n moist, chopped excelsior, and stored in a cool place for about six veeks.

The manner in which the wrapping was made and the material sed may be briefly described as follows:

Wrapping with cloth.—The cloth used was a cheap black calico of the poorest grade obtainable in the market. (See Pl. VIII, fig. 1, *C.*) This was torn into strips 1 inch wide and 4 or 5 inches long. After the graft was made one end of the cloth was dipped for one-half inch into hot, melted grafting wax. Starting with the other end, the cloth was then wrapped tightly around the scion and the free waxed end pressed down. This completed the operation.

Wrapping with rubber.—The rubber used was of a quality similar to dental rubber, which is also frequently used for insulating wires. (See Pl. VIII, fig. 1, *E.*) It was bought in rolls 1 inch wide and was cut off in such lengths as were necessary to completely envelop the union. The rubber was usually wrapped so as to encircle the union twice, and the free end was fastened with rubber cement applied with a brush.

Wrapping with waxed paper.—Sheets of ordinary unglazed printers' paper were waxed on one side by coating them with hot grafting wax applied with a paint brush. (See Pl. VIII, fig. 1, *G.*) They were then cut into 1-inch strips, ten to twenty sheets being cut at one time, and these again into strips about 4 or 5 inches long. One paper strip was then wrapped around the union, the waxed side toward the graft, the free end being stuck down by pressing on it.

Wrapping with plain thread.—The thread used for the ordinary grafts was machine cotton No. 9. (See Pl. VIII, fig. 1, *A.*)

Wrapping with waxed thread.—The waxed thread used was machi cotton No. 28. This was soaked in hot grafting wax until tho oughly penetrated and was then allowed to drain while hot. (S Pl. VIII, fig. 1, *D.*)

Waxing the union.—Ordinary grafts were made with plain threa wrapped as previously described, and then the union of scion ar root was coated with melted grafting wax nearly at the poin hardening. (See Pl. VIII, fig. 1, *B.*)

Unwrapped grafts.—The grafts left without wrapping of any ki were made with special care, so that when the roots and scions w joined they remained quite firmly united. (See Pl. VIII, fig. 1, *F.*)

Results of experiments.—As these root grafts were made they we divided into eight equal duplicate sets. One set was planted in Apr 1905, in each of the cooperative plats 1 to 8. (For description see 78.) All plats showed a fair stand in November, 1905. The tre grown from these grafts made with No. 1 seedlings and scions corr sponding in diameter were from the beginning larger and more vigo ous than any other lot of trees planted at the same time in oth parallel experiments in which No. 2 seedling roots were used. Thi was the case even where scions of the same varieties were used This proves that No. 1 seedlings are the best for root grafting.

In cooperative plats 1 to 4, one-third of the trees were dug at th end of one year, taking every third tree in each row; one-third at th end of the second year, taking each alternate tree in the row; and th remaining trees at the end of the third year. The results from thes plats, designated as experiment 1, are given in Table XXXVIII, i the appendix.

Of the trees in cooperative plat 6, one-third were dug at the en of one year, taking every third tree in each row, and the remainin trees at the end of two years. The results from this plat, designate as experiment 2, are given in Table XXXIX.

Of the trees in cooperative plat 5, one-half, taking each alternat tree in the row, were dug at the end of the second year and the remaining trees at the end of the third year. The results from this experiment, which is designated as experiment 3, are given in Table XL.

All of the trees in cooperative plats 7 and 8 were dug at the age of 2 years. The results from these plats, designated as experiment 4, are given in Table XLI.

In order to show the general results from each kind of wrapping on 1-year-old, 2-year-old, and 3-year-old trees, the results from the four experiments are combined in Table XLII.

Finally, the results of the four wrapping experiments in cooperative plats 1 to 8 are summarized in Table XLIII for convenience in comparison and in summing up the results.

There were planted 3,600 root grafts with each kind of wrapping. e percentage of healthy trees grown from each set, given in order m the highest to the lowest, is as follows: Cloth, 78.2; rubber, .4; waxed paper, 62.5; waxed thread, 60.5; plain thread, 60.3; no apping, 49.6; and wax covered, 28.5.

The results from this series of experiments are comparable, con- ering the varying physical conditions of the plats in which the es were grown, since other conditions were similar. There is but slight variation in the experiments in the percentage of trees dis- sed in the case of each kind of wrapping. It is for this reason that e results from each experiment are given separately.

The conclusions taken from the experiment as a whole are these: oth is the best wrapping to use. Rubber is almost equal to cloth, t its cost is prohibitive. Waxed paper is a little better than dinary thread wrapping, which is again better than waxed thread. e other two methods are not worth considering.

The percentage of trees in each set lost by disease, considering each seased tree as a cull, is as follows: Cloth, 12.1; rubber, 15.7; waxed per, 22; plain thread, 25; waxed thread, 28.6; no wrapping, 31.5; d wax covered, 38.2. These percentages do not include the root afts that died.

The best way to consider the results of the experiment from the rseryman's standpoint is to estimate the number of healthy trees the acre that would be obtained by each method of wrapping. Not early all root grafts that are planted grow. Many die before they rike root, owing to various causes, such as the breaking of the callus the union by careless bundling, poor soil, and conditions at the me of planting, etc. If 15,000 root grafts are required to plant an re, the number of healthy trees to be obtained from each kind of rapping, on the basis of the results from this experiment, is as llows: Cloth, 11,730; rubber, 10,610; waxed paper, 9,375; waxed read, 9,075; plain thread, 9,045; no wrapping, 7,440; and wax vered, 4,275.

If apple trees are worth 8 cents each wholesale, the gain from e use of cloth wrapping as compared to the ordinary plain thread rapping is 2,685 trees, or $214.80 per acre.

Attention is called to the fact that to get the best results any rapping must hold the parts firmly together and that the union hould be entirely covered, especially the lower end of the scion piece. t should also be noted that the cloth used was not waxed cloth, but rdinary cloth, a cheap calico without wax, except to fasten down e end. Waxed cloth may serve its purpose in preventing excessive rmation of callus and in keeping out germs, but often does not rot away soon enough to prevent a constriction of the tree at the point of wrapping.

It is suggested where cloth or cheap calico is used for wrapping that sections of the proper width be cut from the end of a bolt of cloth, using an ordinary lever paper trimmer, such as is found in printing shops. This will give narrow strips of cloth which can be placed on a reel in front of the wrapper. In nursery practice it has been found best and quickest to secure the end of the cloth after the graft has been wrapped by tying it with a half hitch instead of waxing it down. In no case should the cloth or any other wrapping be secured by drawing it under the end of the scion tongue, because anything placed at this point will act as a disturbing element and tend to increase the formation of callus and to permit the development of crown-gall.

LATER EXPERIMENTS IN WRAPPING ROOT GRAFTS.

A number of nurseries tried wrapping with cloth in 1908, and all that have reported to this office obtained good results. Some also report good results with waxed cloth and waxed paper.

Some nurserymen use raffia in place of thread for wrapping root grafts with good success. The method they use in wrapping is shown by Plate VIII, figure 1, *I*. In a small experiment in a greenhouse in 1906 raffia was found to be equally as good a wrapping as cloth when used as shown in Plate VIII, figure 1, *H*. There are two objections to the use of either cloth or raffia. The first is the increased expense of wrapping; the second is that neither is applied by the ordinary wrapper, who is usually a boy, in an effective manner. The lower end of the scion is often not bound down closely, allowing the formation of abundant callus and defeating the very purpose for which the cloth and raffia are intended.

As to what constitutes an ideal wrapping for root grafts the writer has repeatedly put himself on record in these words:

> An ideal wrapping should hold the root and scion pieces together firmly till the root graft has been planted in the nursery row. It should then rot quickly away.

The superiority of cloth as a wrapping has resulted in the invention by two different persons, one in Missouri and one in Alabama, of a continuous thread wrapping for grafts, which is applied evenly and closely over the surface of the union, just as thread is wound on a spool, and which is apparently superior to either cloth or raffia. (See Pl. IX, fig. 2, *B*.) In 1908 a test was made of this continuous thread wrapping for root grafts in comparison with the ordinary thread wrapping. (See Pl. IX, fig. 2, *A*.) Five hundred apple grafts were prepared in each manner, using scions from the Wealthy apple, a variety very susceptible to crown-gall and hairy-root. The grafts were planted on the Arlington Experimental Farm of this Department and grown for one season in a moist, stiff, heavy, clayey soil. The results were as follows:

Of a total of 470 trees grown from grafts with continuous fine thread wrapping, 38.1 per cent was diseased with crown-gall and 16.8 per cent with hairy-root. Of a total of 419 trees grown from grafts with ordinary fine-thread wrapping, 48.7 per cent was diseased with crown-gall and 25.2 per cent with hairy-root. This is a difference of 19 per cent in favor of the new thread wrapping, aside from an increase in the stand of 10.2 per cent, indicating that it will probably prove to be as good as cloth, if not better. The new thread wrapping when applied with a machine made for the purpose can be used with far greater rapidity than any wrapping hitherto in use, and as it holds the union more firmly together it is destined, for this reason alone, to supersede the ordinary wrapping.

None of the forms of wrapping mentioned will prevent the formation of galls and of woolly-knot on the scion of a root graft above the union, since these occur above the wrapping, especially in such varieties as the Wealthy (Pl. II, fig. 3). In the case of Wealthy trees, such occurrence of disease on the scion often equals, or even exceeds, that at the union, as was noted in the foregoing experiment. To reduce this loss, budding or top-grafting must be resorted to, since wrapping reduces only the disease occurring on the union. In the nursery top-grafting is not practicable, owing to the amount of time that it consumes. The additional labor adds to the expense, so as to make the process unprofitable for the grower; not so with the orchardist who grows a few trees and who wishes to take the time. The Walbridge is a good, vigorous-growing tree, quite free from crown-gall, and is recommended as a good stock for top-grafting with the Wealthy in an orchard. The Walbridge and the Wealthy are hardy with reference to cold, and such a combination of scion and rootstalk should do well in the northern apple-growing States in the Mississippi Valley, such as Nebraska, Iowa, and other States in the same latitude.

THE USE OF WEAK ANTISEPTICS FOR THE PREVENTION OF DISEASE IN ROOT GRAFTS OF DOUBTFUL VALUE.

At various times a number of nurserymen have tried dipping scions and seedling roots in weak solutions of copper sulphate, either before or after making them into root grafts. Those who have experimented have reported little or no results in the prevention of disease.

In order to test the use of copper sulphate, an experiment was conducted with two equal sets of root grafts, planted, prepared, and grown under the personal supervision of the writer. Both the scions and the seedling roots were grown in Virginia. The reason the stock was obtained from Virginia is that certain writers have insisted that most of the crown-gall comes from the West, especially from Kansas. Scions were taken of the following varieties: Wealthy, Gano, and Northern Spy. Before cutting it up into pieces for the root grafts two-fifths of the stock, both scions and seedlings, were dipped and thoroughly washed in a 2 per cent solution of copper sulphate in water. The grafts were made in the ordinary manner of making commercial whip grafts, except that care was used in fitting the scion and root pieces together. The results of the experiment are given in Table XLIV, in the appendix.

The results show a considerable decrease of crown-gall and hairy-root (13.8 per cent) in the case of the trees grown from disinfected stock, but this is more than offset by the decreased stand, which was less than one-half of that of the untreated trees. It is quite probable that there was enough copper sulphate present to interfere with the formation of the union in the graft, and it may yet be found that the use of a more dilute solution will prove beneficial. The experiment at least paves the way for further experimentation along this line with less concentrated solutions. Many of the scion pieces treated in the experiment died, while the seedling roots lived, thus indicating an imperfect formation of callus in the union, probably due to the action of the poison.

PACKING AND STORING ROOT GRAFTS.

There can be no question but that the packing and storing of root grafts before planting are of vital importance in the prevention of disease. Care should be taken to use fresh new packing for this purpose, avoiding the use of material or boxes which have been used for packing trees that may have been diseased. The time of formation of callus in the root graft is the most critical in the growth of the tree, and for this reason the grafts should be cared for with the greatest solicitude.

In order to prevent the excessive formation of callus, which predisposes the grafts to attacks of the disease, it will be necessary to follow one of two procedures. The best method is to pack the grafts in clean moist sand, and after a few days' favorable growing temperature store them in cold storage but slightly above freezing, keeping them there until planting time. Good results may be obtained by a second method, in which a cool cellar is used for the immediate storage of root grafts as fast as they are made. This method answers well if the temperature of the cellar can be kept at about 40° to 45° F., so that callus will form very slowly and the growth of shoots and roots will be held back.

For the proper development of callus in apple grafts, as already ntioned, it was found that sand was the best material for packing. e materials used in the experiment were steam sterilized. It will t be easy to thoroughly sterilize sand in the nursery unless improved chinery is invented, but with a little ingenuity in the arrangement perforated steam pipes through the sand container, whether it be box or a bin, most of the sand in use can be sterilized. Moss or celsior can easily be sterilized more or less thoroughly by putting in a barrel or box and passing through it live steam from a pipe. is will rid the packing material of fungi, a number of which are und attacking grafts improperly stored. Two such fungi are cer-inly species of Botrytis and Fusarium.

TIME OF PLANTING ROOT GRAFTS.

If root grafts are put in cold storage they can be held in good ndition till the proper time for planting in the spring. If the cilities for holding back growth in root grafts are poor, then early anting is necessary. Do not allow the root grafts to form exces-ve callus and start to grow (Pl. VIII, fig. 2). In the writer's periments the highest percentage of crown-gall occurred under ch conditions.

CARE IN THE CULTIVATION OF TREES IN THE NURSERY.

It has been shown that root grafts acquire crown-gall chiefly ring the first season's growth and that much of the crown-gall l. II, fig. 3) and woolly-knot (Pl. VI, fig. 5) on certain varieties, ch as the Wealthy, occurs on the scion portion of grafted trees ar the surface of the soil. An examination of such galls usually ows the presence of a wound in the tissues at the base of each. his wound was evidently made with a hoe in cutting out weeds in e row while the trees were young. For this reason care should be ken to avoid wounding trees in cultivation.

When apple seedlings have been budded care should be taken not ridge the dirt about the trees until the bud wounds have at least rtially healed. If the trees are cultivated immediately after budding, crown-gall is often communicated to the callus forming in the esh wound. It is better to cultivate a short time before budding ther than just after.

LECTION OF HEALTHY TREES FOR THE SCION ORCHARD NECESSARY.

The matter of securing healthy scions for root grafting is impor-ant, as has been shown by the experiments with apparently healthy cions taken from trees with the roots diseased with crown-gall and airy-root. It was shown that the use of such scions increased the mount of disease present in root-grafted trees (see pp. 23 and 25).

The planting of cull trees in the scion orchard can not be to strongly condemned, since the greater number of such trees are diseased with forms of crown-gall and hairy-root. Only healthy, vigorous trees should be planted in the scion orchard. Any tree i such orchards that shows even a trace of disease should be removed A scion orchard should be used only as long as it is healthy and vigorous; then it should be replaced by a new orchard.

SELECTION OF THE BEST KINDS OF SOIL FOR GROWING TREES.

It is well known to experienced nurserymen that only certain tract of land in any locality are suitable for growing trees. It has bee strongly indicated by the results of the writer's experiments tha heavy, wet, clayey soils increase the amount of crown-gall present, and that trees on many well-drained soils show the least disease. In general the light, loamy, well-drained soils, where fertile, are th best for growing apple trees with a minimum of disease.

CURE OF DISEASED TREES IN THE ORCHARD.

Experiments by others.—When an apple tree has become diseased with crown-gall and hairy-root it is a question as to whether any curative method can be used to insure a healthy growth. Some writers, notably the following, have advocated cutting off the tumors:

Howard (24), of Missouri, carried out the most extensive experiment in an attempt to cure crown-gall. He studied the subject for two years, employing many different remedies and combinations and experimenting with nearly 3,000 trees. He used the following: Copper sulphate (bluestone), iron sulphate (copperas), sodium chlorid (common salt), lime, sulphur, formalin, ammonia water, bichlorid o mercury (corrosive sublimate), copper carbonate, carbolic acid, hydrocyanic acid, potassium dichromate, mercuric cyanid, silv nitrate, gas tar, kerosene oil, Bordeaux mixture, and hot water.

The remedies were used in three ways: By dipping the roots the materials; by sprinkling the soil with the solutions until th surface was wet just as trees were being planted; and by cutti away the galls and covering over the wounds with the materials prevent their growing again. Howard's results show that some the compounds did prevent the growth of the galls, but not withou injury to the tree. He says that "copperas, bluestone, and lim mixed together and applied to the wound was the best remedy of for preventing a new growth of galls, although this was not entirel efficacious." He mentions no control in which the galls were remove without treatment with fungicides.

Butz (7), in Pennsylvania, took 60 apple trees and cut off the gall from 40, one-half of which he dipped in Bordeaux mixture befor anting; the other 20 were planted without removing the galls, ter dipping in Bordeaux mixture. After two seasons of growth, which none of the trees died, no result from the treatment was tained, as all of the trees still showed the disease.

Clinton (8) reports as follows from Connecticut:

> In 1899 Doctor Sturgis set out on the station grounds ten young trees affected with ots; part of these had the knots cut off, others had knots cut off and roots then ated with copper sulphate, and some were left with knots on. After three seasons growth these trees were dug by the writer and the roots carefully examined. Very tle difference could be seen in any of the trees at this time, and the knots had read very little, if any.

Norton (37) says: "Apple trees slightly affected, often apparently cover and make good trees, but even then the life of the tree may cut short and the ground infected."

Garman (15) advocates the removal of the diseased parts with a nife, but does not consider this treatment satisfactory, as it is kely to weaken the tree.

Alwood (2), experimenting with seven trees, from which he cut ff the galls, giving the trees a subsequent treatment with strong ordeaux mixture, found that several of them showed a characteristic rowth of crown-gall; two made a more normal growth.

Recommendations for the treatment of the disease in orchards.—The uestion as to whether it is advisable to remove the galls from trees an orchard depends, first, upon whether the presence of the gall in self is of greater injury to the tree than the effect of the wound reulting from its removal combined with that of the antiseptics used or treating the wound; and, second, upon the danger of the disease preading to other trees. In an apple orchard, from the results of he writer's experiments, it appears that there is no danger of a erious spread of this disease to other apple trees.

There is very good reason to conclude from the writer's experinents and studies that small knots, swellings, or tufts of roots on rchard trees have no effect on their growth. Where these knots, tc., can be removed without serious injury to the tree, it may be est to remove them. Knots or stem tumors on the outer limbs or wigs may be removed when they first appear. In cases where there re small growths, galls, or woolly-knot, on the trunks or roots of arge, valuable trees (Pl. IX, fig. 1), it will not pay to injure the runk of the tree by their removal.

Howard's experiments, previously cited, prove the futility of cutting crown-galls from the young apple trees and treating them with antiseptics. The trees used in his experiments, if they had not been treated, might be alive and bearing to-day.

In a small experiment with seedling trees, the writer cut off the soft galls from a number of yearling seedlings and planted the seedlings in a nursery row without further treatment. Of those living at the end of one year, 14, or 36.8 per cent, recovered; 16, or 42.1 per cent, developed traces of crown-gall; 3, or 7.9 per cent, developed large galls; and 5, or 13.2 per cent, developed hairy-root. At the same time there were planted in an adjacent row a number of the same lot of seedlings with both hard and soft galls remaining attached. During one season's growth 12, or 37.5 per cent, made no further development; 15, or 46.9 per cent, increased in size in pace with the growth of the tree; and 5, or 15.6 per cent, developed hairy-root from their surface. All that lived made a good growth. Of the first lot 25 per cent died, presumably nearly all from wounds, and of the second lot only 3 per cent died.

In planting an orchard it is better to plant healthy trees and take no risk of diseased trees recovering, since only about one-third of the trees diseased with crown-gall, as shown by experiments, fully recover. The initial cost of the orchard is only a small portion of the total cost of maintenance, and in general it pays to plant the best rather than to plant and attempt to cure diseased trees.

SUMMARY.

The disease or diseases of apple trees manifested by the forms or types known as crown-gall and hairy-root occur in nurseries and orchards in the United States wherever apple trees are grown. They have been reported in one or more forms from Europe, South Africa, New Zealand, and Australia.

The crown-gall type of the disease occurs on apple trees in two forms; the soft and the hard. The former differs slightly from the latter, especially in its more rapid growth, softer texture, and less permanent nature. Apple crown-gall in both forms is related to the crown-gall of the almond, apricot, blackberry, cherry, chestnut, grape, peach, pear, plum, prune, raspberry, rose, and walnut.

The hairy-root type of the disease is of four forms: The simple form, characterized by numerous roots springing at right angles from a larger or main root; the woolly-knot form, characterized by numerous more or less parallel roots springing from a hard gall or swelling on a longer root; broom-root, a side root which is much fasciated with fine branch roots, often negatively geotropic; and aerial tumors, or knots, which are the woolly-knot form on the limbs of the trees. All of these forms of hairy-root are probably directly related to the forms of crown-gall, but for convenience and clearness they are discussed and treated separately.

The soft form of crown-gall is most common on yearling apple seedlings, though usually not abundant. It is occasionally found on budded and root-grafted trees. The hard form is common on budded and much more abundant on root-grafted trees. Hairy-root of the simple form is frequent on apple seedlings and on budded and root-grafted trees. The woolly-knot form of hairy-root is the most common form of the disease, especially on 3-year-old root-grafted trees in the nursery and on orchard trees. The broom-root form occurs occasionally on trees grown on loose soils.

Crown-gall of both forms develops chiefly the first year on seedlings and root-grafted trees in the nursery. It gains entrance almost entirely through wounds. On root-grafted trees it occurs most commonly on the lower end of the scion at the union. In the experiments less crown-gall was found on nursery trees the second and third years than the first, which is strong evidence that it ceases to develop to any great extent. Hairy-root develops on root-grafted trees to some extent the first two years, and to a less extent the third.

In the experiments varying the depth of planting the union had little effect on increasing or decreasing the amount of disease present in apple trees grown from root grafts, but a better stand of trees was obtained by the shallower planting of the union. Very little difference was shown in the amount of disease resulting from the use of the upper half and the lower half of seedling roots for making root grafts.

An increase of both crown-gall and hairy-root occurred in root-grafted trees when apparently healthy scions or roots were taken from trees otherwise diseased. The use for making root grafts of roots from apple seedlings diseased with the simple form of hairy-root resulted in an increased stand of trees in the nursery, but also in a large percentage of inferior trees diseased with hairy-root of the simple form. The disease did not as a rule extend from the root to the scion portion of the tree during the three years of growth in the experiment. Cuttings from seedlings diseased with this form of hairy-root usually sent out roots more readily than healthy cuttings and often developed into vigorous-growing trees.

Where scions for root grafts were taken from yearling trees and from bearing trees in the orchard, no great difference in the number of healthy trees obtained from either was noted, but there was a slight increase of disease in the trees from the scions taken from yearling stock.

Leaving a bud near the lower tip of the scion did not increase the disease in trees grown from root grafts. No great difference in the amount of disease present in trees from root grafts was noted where seedlings grown from both French and American seed were used. The results, however, were decidedly in favor of stock grown from American seed, since the stand of trees with the latter was 25 per cent better.

No essential difference was noted in trees grown from root grafts made from healthy seedling trees taken from a locality where nursery stock had been grown for many years as compared with those taken from a new locality where stock had not been grown previously.

Heavy, stiff, clayey, wet soils apparently increase the amount of disease, especially of crown-gall, in nursery stock. Some lighter soils show an increase of hairy-root.

In nursery experiments the amount of crown-gall present after the first year decreased considerably from year to year, while hairy-root increased slightly, especially during the first two years. In the orchard experiments the amount and intensity of the forms of the disease decreased instead of increasing, indicating that older apple trees in many cases successfully resist both hairy-root and crown-gall and that many may recover completely.

Crown-gall and hairy-root affected nursery trees in the experiments, stunting them very slightly and causing them to be only 90 to 94 per cent as large as healthy trees. In the experimental orchards the apparent effect on the growth of trees was even less—in fact, hardly perceptible. These experiments prove that the effect of crown-gall and hairy-root upon apple trees in the orchard has been overrated, at least in the established apple districts of the Central and Eastern States.

A marked difference in the susceptibility of varieties of apple trees to crown-gall and hairy-root has been noted. Trees of some varieties, when grown from root grafts, tend to develop a large amount of crown-gall; others of hairy-root, in both cases chiefly on the scion portion of root-grafted trees. In these experiments, the Wealthy, the Yellow Transparent, and the Wolf River were the varieties most diseased with crown-gall; and the Ben Davis, the Wolf River, and the Northern Spy were most diseased with hairy-root.

The period when most apple root grafts become diseased with crown-gall is apparently the time when the wounds in the union are being healed by the formation of callus. If the disease could be kept out during this period it is quite probable that little would occur on nursery stock except as it gained entrance later through wounds made in cultivation.

In the experiments, with the fitting of root grafts, where poorly fitted, especially if the lower end of the scion projected, an increase of both crown-gall and hairy-root occurred. The disease apparently did not spread from tree to tree in the nursery rows in the experiments, since there was little or no increase of disease after the first year.

Little of the crown-gall occurring in root-grafted trees can with certainty be accredited to the fact that grafting knives as a rule are not sterilized.

Root grafts should be carefully fitted, especially with respect to the wer end of the scion, which should have a sharp end rather than a lunt one. The wrapping used should cover the union completely nd should firmly hold the parts together until the graft is planted in he soil; then it should rot away when growth begins.

In a large number of wrapping experiments cloth wrapping gave he best results. In a later experiment good results were obtained ith a continuous-thread wrapping applied by a machine evenly and losely over all the union.

Sand was found to be the best material tested for packing and storng root grafts. Cold storage is best for root grafts that must be kept or some time before planting, since it prevents the overdevelopment f callus, a condition which favors the entrance of disease.

RECOMMENDATIONS.

The crown-gall and hairy-root of apple trees is primarily a nursery disease, gaining entrance most frequently the first year. In a wellegulated nursery it is desirable to grow and sell the best trees that can be obtained and at the same time not increase the cost of producion. With this in view the following recommendations are made:

(1) In order to keep the nursery as free as possible from the disease all diseased trees should be left in the field at the time of digging and burned as soon as dry.

(2) The nurseryman should, as far as possible, get scions from healthy trees by growing them under careful selection or purchasing them from others who do this. Never plant diseased trees in the scion orchard.

(3) Buy the best grades of healthy seedlings for budding and root grafting. Insist that growers of apple seedlings cull out and burn all diseased ones at the time of digging.

(4) Make close-fitting root grafts, avoiding blunt ends of the root and scion in the union. Wrap with unwaxed cloth or continuous-thread wrapping, covering completely and firmly the wounded edges in the union. The root and scion should be approximately of the same diameter.

(5) Store root grafts preferably in sand. If the period of planting is delayed beyond two weeks they should be placed in cold storage at a temperature a few degrees above the freezing point.

(6) Plant the union of root grafts about 3 to 4 inches below the surface of the ground. Be careful not to break the callus in planting and avoid wounding the young plants in cultivation.

(7) Propagate by budding, as far as possible, the few varieties most susceptible to crown-gall and hairy-root. Among these are the

Wealthy, the Yellow Transparent, the Wolf River, the Ben Davis, and the Northern Spy.

(8) Avoid heavy, wet soils, since they favor an increase of disease.

(9) Growers of seedlings should avoid wounding the young trees with the hoe or other implements of cultivation.

That these precautions will decrease the disease is certain, as shown by the results of experiments, and an increased profit will result from their use. For example, wrapping with a close, tight, cloth covering decreased the percentage of diseased trees 12.9 per cent and resulted in an increase of stand amounting to 23.9 per cent of the original root grafts planted. This, based on 15,000 grafts to the acre, is a saving of $214.80 per acre. The continuous wrapping of root grafts with thread is more easily and cheaply done and promises to give equally as good results.

The orchardist is advised to plant the healthiest trees obtainable, since the initial cost of the orchard is only a small part of the final outlay. If a tree becomes diseased during the first three or four years so that its growth is hindered, dig it up and plant a healthy tree in its place. If trees in an older orchard are diseased, but still bearing profitable crops, allow them to remain in the orchard, unless there is danger of infecting more profitable plats of raspberries, grapes, or peaches. In such case they should be removed, since crown-gall from the apple tree may infect these plants.

If the growing of nursery stock were confined to apple trees, nursery inspection for crown-gall would hardly be necessary. Since the disease attacks and kills grapevines, raspberries, and probably peach trees, and since it may be communicated to them from apple trees, it is clearly the duty of a nursery inspector to insist that apple trees diseased with crown-gall shall not be sold. It is best to include in the same category apple trees diseased with hairy-root.

On the other hand, an inspector should be certain that apple trees are diseased with crown-gall or hairy-root before condemning them. Warts and pimples are not necessarily crown-gall, nor are fibrous roots certainly hairy-root. The tendency to form fibrous roots exists under certain soil conditions (Pl. III, fig. 4). In some localities and under certain soil conditions healthy trees with much-branched, fibrous roots are grown. These roots are to be distinguished from hairy-root formation, which is characterized at the beginning by clustered, fleshy, often fasciated roots, which later become fibrous through shrinking. Only plainly diseased trees should be rejected; other trees in the bundle should not be condemned on account of the presence of a diseased tree, but as a matter of precaution should be dipped in a weak solution of some antiseptic, as one-tenth of 1 per cent of corrosive sublimate, for five minutes and washed in water before planting.

APPENDIX.

THODS AND CONDITIONS OF EXPERIMENTATION IN THE STUDY OF CROWN-GALL AND HAIRY-ROOT.

In order to prevent useless repetition, a brief description will be ven of the methods and conditions under which each set of experi-ents was performed, the results of which are given in previous apters and in the tables in the following portion of the appendix.

EXPERIMENTS IN THE GREENHOUSE.

All greenhouse experiments were conducted at the Mississippi Valley laboratory, St. Louis, Mo. Seedlings of various kinds of hrubs and trees were grown in pots and benches, as follows: All soil and pots were sterilized for three hours in an autoclave at a temperature of 239° F. The benches were constructed of new pine and cypress lumber. Before filling the benches with soil they were washed with a strong solution of Bordeaux mixture. All seeds before planting were sterilized in one of two ways—either in concentrate sulphuric acid for ten minutes or for an equal time in a one-fifth of 1 per cent solution of mercuric chlorid, followed in either case by repeated washings in sterile water. In these experiments 6,176 plants were grown and used in five years.

EXPERIMENTS IN THE NURSERY.

The experiments in nurseries were extensive and included the planting of 143,763 apple seedlings and root grafts of 256 varieties during a period of six years. They were of two kinds, independent and cooperative. In each experiment all seedlings, cuttings, or scions were selected from the same stock, all root grafts[a] were made and planted equally well in each portion, and all portions of each plat were of uniform soil and drainage and were cultivated equally well, all of the work being done by skilled workmen under the direction and personal supervision of the writer. Many experiments were duplicated in different localities, insuring greater accuracy in results.

Independent nursery experiments.—These were conducted in nursery plats on land owned or leased by the Department and cultivated by its employees. There were three plats of the following description:

Independent plat 1 was located near Louisiana, Mo., on a slightly sloping piece of upland consisting of a heavy, colluvial clay loam. It was situated so that it did not receive the overflow from adjacent fields. It had been planted to field crops for twenty years and had a clover crop when taken for the purposes of experiment. In the experiment on this plat 19,700 root grafts and trees were grown during 1903 and 1904 on 4 acres of land.

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[a] In all experiments where the term "root graft" is used, unless otherwise specified, reference is made to the form of root graft known as whip or tongue graft.

Independent plat 2 consisted of about one-half acre of level land on the Potomac Flats, south of Washington, D. C. It consisted of an alluvial loam, the soil having been formerly pumped by dredgers from the bottom of the Potomac River. In this plat 6,400 root grafts and seedling trees were planted in 1907.

Independent plat 3 consisted of about one-half acre of gently sloping clay loam on the Arlington Experimental Farm, in Virginia, southwest of Washington, D. C. In this plat 6,043 root grafts were planted in 1908.

Cooperative nursery experiments.—Experiments were conducted during the years 1905 to 1908 in cooperation with six of the largest nurseries in the Mississippi Valley. Eight experimental plats, of about 1 acre each, were planted in as many different localities in five States. A total of 113,620 seedlings and root grafts was planted. A description of the plats follows:

Cooperative plat 1 was located in southwestern Iowa on level valley land consisting of a colluvial clay loam. The previous crops for five years were grain.

Cooperative plat 2 was located in southwestern Iowa on sloping upland consisting of a light clay loam. The previous crops for five years were oats one year, corn one year, and plum trees three years.

Cooperative plat 3 was located in southeastern Nebraska on level upland consisting of a loess loam. The previous crops for five years were corn one year and cherry trees four years.

Cooperative plat 4 was located in western Illinois on level upland of heavy black loam mixed with clay. The previous crops for five years were grain.

Cooperative plat 5 was located on level valley land in eastern Missouri consisting of a colluvial loam mixed with some sand. The previous crops for five years were cowpeas one year and peaches four years.

Cooperative plat 6 was located in eastern Kansas on level valley land consisting of an alluvial sandy loam. The previous crops for five years were corn one year, osage orange one year, Kafir corn one year, and apples two years.

Cooperative plat 7 was located in eastern Missouri on level valley land consisting of a colluvial clay loam. The previous crops for five years were cowpeas one year and peaches four years.

Cooperative plat 8 was located in northwestern Arkansas on level valley land consisting of a sandy loam. The previous crops for five years were grain.

EXPERIMENTS IN ORCHARDS.

Four orchards were planted with both healthy and diseased apple es. These were situated on land owned or leased by the Depart-nt. They were located and designated as follows:

Orchard 1 was located near Louisiana, Mo., on a gently sloping ce of upland consisting of a heavy clay loam. The land had been nted to grain and clover for twenty years. This orchard was nted to 208 apple trees.

Orchard 2 was located on the same block of land as orchard 1, t it was lower and wetter in rainy seasons. It contained 261 apple es.

Orchard 3 was also located on the same block of land as orchard 1, t followed the trees grown in independent plat 1. It contained 08 apple trees.

Orchard 4 was first planted on the Potomac Flats, south of ashington, D. C., on built-up land from dredging, similar to that independent plat 3. The 500 apple trees in this orchard after e year were transplanted to a block of land with a colluvial clay am on the Arlington Experimental Farm, in Virginia, where they e now located.

The trees for planting in these orchards were selected as follows: ealthy, vigorous, 2-year-old apple trees with a well-balanced root stem of smooth roots (Pl. III, fig. 3) were selected in each experient for a check or control. To test the effects of the forms of sease there were selected sets of trees of the same varieties, of ual size, and from the same stock of trees, some of which were seased with crown-gall (Pl. I, fig. 1) and others with hairy-root Pl. I, fig. 2). All of the trees used in the experiments were selected y the writer. Both healthy and diseased trees were planted and nded equally well.

All of the data on these orchard and nursery experiments were ersonally recorded by the writer, notes being taken on each indiidual tree.

TABLES GIVING THE RESULTS OF EXPERIMENTS IN THE STUDY OF CROWN-GALL AND HAIRY-ROOT.[a]

TABLE I.—*Development of crown-gall and hairy-root on transplanted seedlings in the nursery.*

Age of seedlings.	Number of seedlings.	Seedlings, galled.	Seedlings, hairy.
Years.		*Per cent.*	*Per cent.*
1	350	0.6	3.1
2	116	1.4	11.7
3	114	1.5	9.4

TABLE II.—*Comparative development of crown-gall on grafted and budded trees in the nursery.*

Variety.	Year.	Grafted trees.		Budded trees.		Decrease in budded trees.
		Smooth.	Galled.	Smooth.	Galled.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ben Davis	1904	78	22	91	9	[illegible]
Do	1905	60	40	92	8	[illegible]
Black Annette	1904	89	11	99	1	[illegible]
Grimes	1905	70	30	99	1	[illegible]
Oldenburg	1904	83	17	96	4	[illegible]
Do	1904	89	11	99	1	[illegible]
Wealthy	1904	54	46	93	7	[illegible]
Do	1904	83	17	97	3	[illegible]
Do	1904	88	12	98	2	[illegible]
Yellow Transparent	1904	94	6	99	1	[illegible]
Do	1904	89	11	92	8	[illegible]

The data in Table II are given from a number of localities in the Mississippi Valley, Virginia, and North Carolina. The names of the nurseries are withheld because the reports were confidential. At the time the reports were received, most nurserymen designated as "crown-gall" all forms of crown-gall and hairy-root, and in the table they are combined under the term "galled."

TABLE III.—*Results on the health of trees of varying the depth of the union in planting root grafts.*

Year.	Trees with long scions.		Trees with short scions.	
	Number.	Diseased.[b]	Number.	Diseased.[b]
		Per cent.		*Per cent.*
1905	754	13.3	769	13.3
1906	980	35.0	870	[illegible]
Total	1,734	25.5	1,639	32.0

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[a] In these tables both forms of crown-gall are included under the term "galled," and all of the forms of hairy-root under the term "hairy," unless otherwise specified. The word "smooth" is used to designate trees free from the disease.

[b] In this table the term "diseased" includes "galled" and "hairy" trees.

BLE IV.—*Results on the health of trees of varying the depth of the union in planting root grafts, second experiment.*

Year.	Trees with long scions.			Trees with short scions.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
5.	1,288	21.3	7.6	1,446	20.9	7.5
6.	2,450	6.6	10.6	2,960	5.3	13.2
7.	1,079	.1	8.6	1.182	1.6	9.1
Total	4,817	9.4	7.5	5,588	8.6	10.8

BLE V.—*Results on the health of trees of selecting upper and lower piece roots for root grafts.*

Year.	Trees from grafts on upper piece root.			Trees from grafts on lower piece root.		
	Number dug.	Galled.	Hairy.	Number dug.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
05.	743	19.8	7.7	703	22.0	7.4
06.	1,675	6.0	15.1	1,285	4.5	10.6
07.	580	1.9	10.9	602	1.3	7.5
Total	2,998	8.6	12.5	2,590	8.5	9.0

ABLE VI.—*Results on the health of trees of using seedlings diseased with hairy-root in root grafting, first series of experiments.*

Year.	Trees with hairy-root grafts.			Trees with smooth-root grafts.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
First	1,132	11.5	73.8	751	24.8	7.9
Second	1,922	4.8	79.2	1,481	8.7	11.0
Third	922	7.4	76.5	632	7.1	10.9
Total	3,976	7.3	77.0	2,864	12.6	10.2

TABLE VII.—*Results on the health of trees of using seedlings diseased with hairy-root in making root grafts, second series of experiments.*

Year.	Trees with hairy-root grafts.			Trees with smooth-root grafts.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
First	141	1.4	90.8	125	18.4	5.6
Second	268	2.2	84.2	245	3.7	10.6
Third	81	6.2	72.8	99	2.0	9.1
Total	490	2.6	83.7	469	7.3	8.9

TABLE VIII.—*Results on the health of trees of using seedlings diseased with crown-g in making root grafts.*

Year.	Trees with smooth-root grafts.			Trees with galled-root graft		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy
		Per cent.	*Per cent.*		*Per cent.*	*Per cen*
First	125	18.4	5.6	118	27.1	[illegible]
Second	245	3.7	10.6	165	20.1	[illegible]
Third	99	2.0	9.1	107	13.1	[illegible]
Total	469	7.3	8.9	390	20.2	[illegible]

TABLE IX.—*Comparison of the results on the health of trees from the use of scions fr young and old trees in making root grafts.*

Year.	Trees with scions from young trees.			Trees with scions from old trees.		
	Number dug.	Galled.	Hairy.	Number dug.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cen*
1905	229	17.5	6.1	215	8.3	[illegible]
1906	297	6.1	19.7	382	6.3	[illegible]
1907	207	.5	15.0	193	1.0	[illegible]
Total	733	8.0	14.0	790	5.6	[illegible]

TABLE X.—*Comparison of the results on the health of trees of root grafts on seedling root grown from French and from American seed.*

Year.	Trees from French seed.			Trees from American seed.		
	Number dug.	Galled.	Hairy.	Number dug.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1905	491	46.8	2.7	528	42.8	[illegible]
1906	913	11.7	6.8	1,282	6.0	[illegible]
1907	398	1.7	7.3	445	4.0	[illegible]
Total	1,802	19.1	5.8	2,255	14.2	[illegible]

TABLE XI.—*Results on the health of trees of using seedlings from localities where nursery stock has been grown for many years.*

Year.	Trees from an old locality.			Trees from a new locality.		
	Number dug.	Galled.	Hairy.	Number dug.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1905	937	40.2	3.5	491	46.8	[illegible]
1906	1,816	7.9	5.5	913	11.7	[illegible]
1907	738	3.6	4.1	398	1.7	[illegible]
Total	3,491	15.7	4.7	1,802	19.1	[illegible]

LE XII.—*Results on the health of trees of heavy, wet soil compared with drier soil in the same locality.*

n- of t.	Nature of soil.	Trees grown.			
		Number.	Healthy.	Galled.	Hairy.
			Per cent.	*Per cent.*	*Per cent.*
...	Heavy, wet loam	5,018	75.1	19.4	5.5
...	Light, drier loam	6,038	75.9	14.1	10.0

LE XIII.—*Results on the health of trees of heavy, wet soils compared with dry soils in different localities.*

n- of t.	Nature of soil.	Trees grown.		
		Number.	Healthy.	Diseased.
			Per cent.	*Per cent.*
...	Heavy, wet loam	4,460	76.6	23.4
...	.....do	4,798	77.9	22.1
...	Light, loess loam	4,454	86.0	14.0
...	Light, sandy loam	4,809	87.7	12.3

LE XIV.—*Maximum development of crown-gall and hairy-root, by years, on grafted trees.*

Number of set.	Trees dug.			Galled.			Hairy.		
	First year.	Second year.	Third year.	First year.	Second year.	Third year.	First year.	Second year.	Third year.
	No.	*No.*	*No.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	3,392	3,168	3,254	24.5	13.8	7.7	6.2	9.8	9.7
	1,521	1,434	1,316	47.7	10.3	3.6	3.0	6.3	6.2
	2,161	2,014	2,077	24.2	4.3	1.8	7.5	9.1	8.7
	1,078	1,003	998	13.3	5.1	3.1	2.6	5.3	6.5
	782	745	612	25.3	8.3	3.6	4.1	9.3	9.8
	350	309	321	15.7	6.2	.9	7.4	7.4	11.2
	620	584	567	26.9	6.8	7.6	7.3	10.6	10.6
Total	9,904	9,257	9,145	26.7	9.1	4.7	5.5	8.6	8.7

Total trees in experiment, 28,306.

BLE XV.—*Average height of healthy and diseased root-grafted trees at the age of one year*

Location of plats.	Healthy trees.		Galled trees.		Hairy-rooted trees.	
	Number.	Height.	Number.	Height.	Number.	Height.
		Inches.		*Inches.*		*Inches.*
thwestern Iowa	1,689	35.8	724	32.4	265	32.8
Do	1,293	36.3	759	33.7	169	33.2
theastern Nebraska	1,936	37.0	653	33.1	287	34.0
tern Kansas	1,665	43.1	578	42.4	386	39.9
stern Illinois	1,300	30.5	889	28.8	246	26.6
Total	7,883	37.2	3,603	33.5	1,353	34.0

TABLE XVI.—*Average height of healthy and diseased root-grafted trees at the age of two*

Location of plats.	Healthy trees.		Galled trees.		Hairy-rooted trees.	
	Number.	Height.	Number.	Height.	Number.	Height.
		Inches.		*Inches.*		*Inches.*
Southwestern Iowa	1,902	50.7	302	47.7	411	[illegible]
Do	1,444	63.6	267	57.6	327	[illegible]
Southeastern Nebraska	2,146	52.2	324	50.7	417	[illegible]
Eastern Kansas	2,028	61.6	680	50.4	642	[illegible]
Western Illinois	1,639	52.5	246	48.7	270	[illegible]
Total	10,159	56.4	1,819	51.3	2,267	[illegible]

TABLE XVII.—*Average diameter of healthy and diseased trees in orchards 1 and 2.*

Variety.	Number of orchard.	Healthy trees.		Galled trees.		Hairy-rooted trees.	
		Number.	Average diameter.	Number.	Average diameter.	Number.	Average diameter.
			Inches.		*Inches.*		*Inches.*
York Imperial	1	16	2.64	4	2.10	8	[illegible]
Do	2	47	2.77	8	2.39	22	[illegible]
Total		63	2.74	12	2.29	30	[illegible]
Ingram	1	16	2.48	2	2.42	10	[illegible]
Do	2	23	2.36	9	2.04	10	[illegible]
Total		39	2.42	11	2.10	20	[illegible]
Gano	1	44	2.26	11	2.39	22	[illegible]
Do	2	16	2.16	13	1.88	18	[illegible]
Total		60	2.23	24	2.10	40	[illegible]
Collins	1	39	2.23	4	2.67	14	[illegible]
Do	2	25	2.23	23	2.00	12	[illegible]
Total		64	2.23	27	2.10	26	[illegible]
Total for all varieties		226	2.42	74	2.13	116	[illegible]

TABLE XVIII.—*Number of healthy trees planted of each variety and the number dying in orchards 1 and 2.*

Number of orchard.	York Imperial trees.		Ingram trees.		Gano trees.		Collins trees.		Total.	
	Planted.	Died.	Planted.	Died.	Planted	Died.	Planted.	Died.	Planted.	Died.
1	16	3	16	2	48	3	32	2	112	[illegible]
2	45	5	23	5	27	3	27	0	122	[illegible]
Total	61	8	39	7	75	6	59	2	234	[illegible]

LE XIX.—*Number of diseased trees planted of each variety and the number dying in orchards 1 and 2.*

umber of orchard.	York Imperial trees.		Ingram trees.		Gano trees.		Collins trees.		Total.	
	Planted.	Died.	Planted.	Died.	Planted.	Died.	Planted.	Died.	Planted.	Died.
....	16	1	16	2	32	0	32	5	96	8
....	45	8	31	7	27	4	36	3	139	22
Total..............	61	9	47	9	59	4	68	8	235	30

TABLE XX.—*Number of trees dying in orchard 3 during two years' growth.*

Condition of roots.	Trees planted in 1907.	Trees dead in 1907.		Trees dead in 1908.		Trees alive in 1908.	
	Number.	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
althy..........................	572	182	31.8	9	1.6	381	66.6
lled..............................	177	60	33.9	6	3.4	111	62.7
iry..............................	359	69	19.2	21	5.9	269	74.9

BLE XXI.—*Results of experiments showing the susceptibility of different varieties of apple trees to crown-gall and hairy-root.*

Variety.	Crown-gall.	Variety.	Hairy-root.	Variety.	Crown-gall and hairy-root.	Number of trees.
	Per cent.		*Per cent.*		*Per cent.*	
ealthy..............	34.4	Ben Davis.........	29.9	Wolf River.........	46.4	660
ellow Transparent.	27.1	Wolf River.........	25.3	Wealthy............	43.3	6,221
olf River..........	21.1	Northern Spy......	19.1	Ben Davis..........	36.1	2,870
aiden Blush........	19.1	Grimes............	15.3	Yellow Transparent.	34.0	2,114
ameuse.............	17.8	Gano..............	12.6	Maiden Blush......	26.4	1,698
ldenburg...........	17.7	Northwestern Greening.	10.5	Northern Spy......	26.0	4,166
issouri.............	15.5	Red June.........	10.5	Missouri...........	25.9	5,591
nathan.............	15.1	Missouri..........	10.4	Fameuse............	25.8	552
ed June............	15.0	Scott Winter......	9.3	Red June...........	25.5	2,152
hitney..............	14.8	Rambo............	9.3	Gano...............	24.3	2,284
ambo...............	14.2	Yellow Bellflower.	9.2	Oldenburg.........	24.0	1,883
aldwin.............	11.9	Wealthy..........	8.9	Grimes............	23.7	2,477
ano................	11.7	Walbridge........	8.9	Rambo.............	23.5	1,148
alome..............	11.1	York Imperial....	8.3	Jonathan...........	21.0	1,668
ork Imperial.......	9.9	Fameuse..........	7.4	Whitney...........	20.4	2,287
inkler..............	9.8	Maiden Blush.....	7.3	Northwestern Greening.	18.2	3,963
rimes..............	8.4	Minkler...........	7.0	York Imperial.....	18.1	4,073
orthwestern Greening.	7.7	Salome...........	6.9	Salome............	18.0	623
cott Winter........	7.5	Yellow Transparent.	6.9	Scott Winter.......	16.8	613
ellow Bellflower...	7.3	Oldenburg........	6.3	Minkler...........	16.8	1,251
Northern Spy.......	6.9	Jonathan.........	5.9	Baldwin...........	16.6	1,497
Ben Davis..........	6.2	Martha...........	5.9	Yellow Bellflower..	16.5	546
Walbridge..........	5.2	Whitney..........	5.6	Walbridge.........	14.1	2,328
Martha.............	4.8	Baldwin..........	4.7	Martha............	10.7	1,286

In Table XXI in the first two columns is given the percentage of trees of 24 varieties diseased with crown-gall, arranged in the order of their susceptibility, from the highest to the lowest; in the third and fourth columns is given the percentage of the same varieties diseased with hairy-root, similarly arranged; in the fifth and sixth columns the results of the first four columns are combined; and in the last column is given the total number of trees of each variety grown in five years.

TABLE XXII.—*Results of experiments showing the variation in susceptibility to disease of scions from different localities.*

VARIETY, WOLF RIVER. EXPERIMENT CONDUCTED IN EASTERN KANSAS.

Number of nursery.	Location.	Trees in experiment.			
		Number.	Diseased.	Galled.	Hairy.
			Per cent.	*Per cent.*	*Per cent.*
1	Iowa	244	40.2	20.1	[illegible]
2	.....do	50	38.0	14.0	[illegible]
9	Missouri	250	36.4	17.2	[illegible]
3	.....do	189	33.3	14.8	[illegible]
6	.....do	175	30.8	11.4	19.4
8	Iowa	280	30.3	10.7	[illegible]
5	California	190	26.8	8.9	17.9
4	Michigan	250	26.4	8.0	13.4
7	Ohio	327	22.5	6.4	14.5

VARIETY, WEALTHY. EXPERIMENT CONDUCTED IN EASTERN MISSOURI.

Number of nursery.	Location.	Number.	Diseased.	Galled.	Hairy.
12	Missouri	345	29.6	18.8	[illegible]
11	Kansas	800	25.0	20.1	4.9
1	Iowa	300	23.0	17.6	3.4
10	California	90	22.2	16.7	5.5
3	Missouri	200	21.0	13.0	8.0
9	.....do	85	20.0	14.1	5.9
7	Ohio	377	19.4	14.3	5.1
2	Iowa	190	14.2	7.9	6.3
4	Michigan	315	12.1	8.0	4.1

VARIETY, YELLOW TRANSPARENT. EXPERIMENT CONDUCTED IN EASTERN NEBRASKA.

Number of nursery.	Location.	Number.	Diseased.	Galled.	Hairy.
1	Iowa	309	19.1	2.8	[illegible]
3	Missouri	200	10.0	5.0	5.0
4	Michigan	460	8.7	3.5	[illegible]
2	Iowa	190	7.9	3.2	[illegible]
6	Missouri	177	7.2	1.7	5.6
5	California	335	6.3	1.8	[illegible]

TABLE XXIII.—*Results of experiments showing the comparative communicability of forms of crown-gall and hairy-root.*

Treatment of seedlings.	Seedlings in experiment.		
	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*
1, Control, cut	1,447	0.8	6.6
2, Control, chip inserted	1,426	1.1	6.4
3, Piece of soft gall inserted	1,382	8.7	[illegible]
4, Piece of hard gall inserted	1,324	1.6	6.5
5, Piece from hairy-root seedling inserted	1,330	3.1	[illegible]

BLE XXIV.—*Results from using root grafts inoculated with pieces of apple crown-gall of the soft form.*

Number of experiment.	Age of trees.	Number of trees.	Uninoculated grafts.		Grafts inoculated with gall chip.		Grafts with root chip inserted.	
			Galled.	Hairy.	Galled.	Hairy.	Galled.	Hairy.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
....	1 year...	1,600	25.3	4.1	45.4	3.6	39.5	2.8
....	2 years..	1,445	8.3	9.3	36.6	6.3	10.6	8.3
....	3 years..	1,378	3.6	9.4	19.5	7.6	4.6	10.4
		4,423	10.8	7.5	34.2	5.8	18.9	7.1
....	1 year...	464	4.2	11.1	38.0	17.0	14.7	17.1
....	2 years..	661	14.7	12.9	35.7	20.5	16.5	15.2
		1,125	10.4	12.1	36.5	19.2	15.7	16.0
....	....	1,586	8.0	8.1	22.6	8.8	10.7	10.7
Total....................	....	7,134	11.8	8.5	31.4	8.5	16.5	9.0

BLE XXV.—*Results of experiments showing the increase in the communicability of disease due to defective root grafting.*

Number of experiment.	Age of trees.	Trees with grafts well made.			Trees with grafts poorly made.		
		Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
			Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
....	1 year.....	1,078	13.3	2.6	869	55.0	3.1
....	2 years....	898	5.1	5.3	771	15.3	7.4
....	3 years....	998	3.1	6.5	789	4.3	10.3
		2,974	7.6	5.0	2,429	25.9	6.8
....	1 year.....	268	11.6	4.1	247	51.5	1.6
....	2 years....	447	7.4	9.2	401	16.5	16.2
		715	8.8	7.3	648	29.8	10.7
....	2 years....	1,283	6.9	7.9	1,035	19.9	11.9
Total....................	....	4,972	7.9	5.9	4,112	25.0	8.8

ABLE XXVI.—*Results of experiments with scions taken from trees diseased with crown-gall and with scions from healthy trees.* (*Experiment 1.*)

Variety.	Number obtained from scions from healthy trees.			Number obtained from scions from diseased trees.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Collins....................	122	71	52	105	53	107
Wealthy....................	29	56	21	19	75	10
York Imperial..............	112	24	8	99	36	18
Gano.......................	107	30	33	77	16	33
Jonathan...................	207	36	25	191	58	38
Total......................	577	217	139	491	238	206
Percentage for all five varieties..........	61.8	23.3	14.9	52.5	25.5	22.0

TABLE XXVII.—*Results from experiments with scions taken from trees diseased with crown-gall and with scions from healthy trees.* (*Experiment 2.*)

Variety.	Number obtained from scions from healthy trees.			Number obtained from scions from diseased trees.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Gano	236	3	44	200	16	30
Wealthy	281	93	44	388	169	61
Wolf River	87	2	12	104	14	29
Total	604	98	100	692	199	120
Percentage for all three varieties	75.3	12.2	12.5	68.4	19.6	12.0

TABLE XXVIII.—*Results from experiments with scions taken from trees diseased with hairy-root and with scions from healthy trees.* (*Experiment 2.*)

Variety.	Number obtained from scions from healthy trees.			Number obtained from scions from diseased trees.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Northern Spy	70	0	13	68	3	11
Gano	236	3	44	180	7	50
Wolf River	87	2	12	140	2	25
Charlamoff	87	2	12	30	1	70
Total	480	7	81	418	13	156
Percentage for all four varieties	84.5	1.2	14.3	71.2	2.2	26.6

TABLE XXIX.—*Results from experiments with scions taken from trees diseased with crown-gall and with scions from healthy trees.* (*Experiment 3.*)

Variety.	Number obtained from scions from healthy trees.			Number obtained from scions from diseased trees.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Wolf River	46	20	14	38	6	12
Gano	65	4	35	43	0	23
Wealthy	93	83	11	127	153	38
Total	204	107	60	208	159	73
Percentage for all three varieties	54.9	28.9	16.2	47.3	36.1	16.6

TABLE XXX.—*Results from experiments with scions taken from trees diseased with hairy-root and with scions from healthy trees.* (*Experiment 3.*)

Variety.	Number obtained from scions from healthy trees.			Number obtained from scions from diseased trees.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Wolf River	46	20	14	44	20	35
Gano	65	4	35	47	10	35
Wealthy	93	83	11	37	16	8
Northern Spy	16	6	17	13	0	3
Charlamoff	14	0	7	24	1	34
Total	234	113	84	165	47	118
Percentage for all five varieties	54.3	26.2	19.5	50.0	14.2	35.8

LE XXXI.—*Results from experiments showing the decrease of disease among trees in nursery rows during the second and third years.* (*Experimental set 1.*)

Number of experiment.	Number of trees in experiment.	Diseased trees, first year.		Diseased trees, second year.		Diseased trees, third year.	
		Galled.	Hairy.	Galled.	Hairy.	Galled.	Hairy.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	9,814	24.5	6.2	13.8	9.8	7.7	9.7
	4,271	47.7	3.0	10.3	6.3	3.6	6.2
	6,252	24.2	7.5	4.3	9.1	1.8	8.7
	3,079	13.3	2.6	5.1	5.3	3.1	6.5
	2,139	25.3	4.1	8.3	9.3	3.6	9.8
	980	15.7	7.4	6.2	7.4	.9	11.2
	1,671	26.9	7.3	6.8	10.6	7.6	10.6
Total	28,206	26.7	5.5	9.1	8.6	4.7	8.7

BLE XXXII.—*Results from experiments showing the decrease of disease among trees in nursery rows the second year.* (*Experimental set 2.*)

Number of experiment.	Number of trees in experiment.	Diseased trees, first year.		Diseased trees, second year.	
		Galled.	Hairy.	Galled.	Hairy.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
	2,480	22.6	7.6	19.1	13.1
	1,187	24.7	6.0	12.0	10.5
	1,733	9.1	7.9	2.8	9.7
	1,369	30.7	2.9	11.5	12.5
	1,105	15.1	14.7	20.6	15.4
	201	3.4	13.1	3.4	27.3
	379	14.5	11.4	14.9	12.1
Total	8,454	20.0	7.9	12.8	10.3

ABLE XXXIII.—*Results from experiments showing the decrease of disease among trees in nursery rows the third year.* (*Experimental set 3.*)

Number of experiment.	Number of trees in experiment.	Diseased trees, second year.		Diseased trees, third year.	
		Galled.	Hairy.	Galled.	Hairy.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
	2,308	11.7	6.7	3.3	13.5
	556	12.5	4.3	1.8	4.7
	1,005	6.2	6.8	1.1	10.3
	446	12.6	5.4	9.1	7.2
	642	20.6	4.6	1.9	5.6
	133	9.0	10.4	.0	3.0
7.	136	14.1	14.1	3.1	13.8
Total	5,226	11.7	6.4	2.6	10.2

TABLE XXXIV.—*Condition of the roots of the trees in orchards 1 and 2 at the time of planting.*

Number of orchard.	Number of trees planted.	Healthy trees.		Galled trees.	
		Number.	Per cent.	Number.	Per cent.
1	208	112	53.8	96	46.2
2	261	122	46.7	139	53.3
Total	469	234	49.9	235	50.1

TABLE XXXV.—*Condition of the roots of the trees in orchards 1 and 2 after six years' growth.*

Number of orchard.	Dead trees.		Healthy trees.		Galled trees.		Hairy-rooted trees.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
1	18	8.6	115	55.3	21	10.1	54	25.
2	35	13.4	111	42.5	53	20.3	62	23.
Total	53	11.3	226	48.2	74	15.8	116	24.7

TABLE XXXVI.—*Results from experiments showing the development of disease upon healthy trees grown for six years in orchards 1 and 2.*

Number of orchard.	Healthy trees planted.	Condition of trees after six years.			
		Dead.	Healthy.	Galled.	Hairy.
1	112	10	83	1	1
2	122	13	70	10	29
Total	234	23	153	11	4
Per cent	100	9.8	65.4	4.7	20.1

TABLE XXXVII.—*Results of experiments showing the recovery of diseased trees during six years in orchards 1 and 2.*

Number of orchard.	Diseased trees planted.	Condition of trees after six years.			
		Dead.	Recovering.	Galled.	Hairy.
1	96	8	32	20	36
2	139	22	41	43	33
Total	235	30	73	63	69
Per cent	100	12.8	31.1	26.8	29.3

BLE XXXVIII.—*Results of experiments in wrapping root grafts.* (*Experiment 1.*)

Kind of wrapping.	Trees 1 year old.			Trees 2 years old.			Trees 3 years old.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		P. ct.	*P. ct.*		*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*
th	553	9.9	2.9	538	7.6	4.3	566	2.6	4.6
bber	546	8.6	3.9	478	9.2	8.6	523	5.0	9.5
xed paper	525	25.3	3.8	496	10.5	8.2	508	6.3	10.0
in thread	504	22.2	10.7	486	12.4	11.3	469	7.7	11.3
xed thread	561	31.5	7.5	521	19.8	11.7	520	11.3	9.8
wrapping	391	41.9	9.5	386	14.8	15.8	389	10.5	11.3
xed union	312	46.5	6.1	273	29.7	11.3	273	15.0	12.5

ABLE XXXIX.—*Results of experiments in wrapping root grafts.* (*Experiment 2.*)

Kind of wrapping.	Trees 1 year old.			Trees 2 years old.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
loth	142	9.9	3.5	254	10.2	5.5
ubber	147	10.2	4.1	239	12.5	12.1
axed paper	143	28.7	9.1	238	17.2	12.6
lain thread	148	18.9	10.8	234	19.7	14.1
axed thread	121	24.8	9.9	253	23.3	15.0
o wrapping	144	33.3	7.6	245	21.6	15.1
axed union	65	70.7	7.7	47	42.6	6.4

TABLE XL.—*Results of experiments in wrapping root grafts.* (*Experiment 3.*)

Kind of wrapping.	Trees 2 years old.			Trees 3 years old.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Cloth	201	10.4	8.0	193	3.6	6.7
Rubber	168	7.7	4.8	174	1.7	9.2
Waxed paper	160	11.9	6.3	158	2.5	15.8
Plain thread	173	8.1	10.4	193	4.1	16.6
Waxed thread	185	12.4	6.5	179	4.5	14.0
No wrapping	185	14.6	5.4	174	3.5	18.4
Waxed union	87	21.9	4.6	68	3.0	17.6

TABLE XLI.—*Results of experiments in wrapping root grafts.* (*Experiment 4.*)

Kind of wrapping.	Trees 2 years old.					
	Arkansas plat.			Missouri plat.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Cloth	404	4.0	6.7	340	6.8	5.6
Rubber	385	4.9	10.1	392	5.1	13.5
Waxed paper	374	2.4	13.1	292	8.6	14.0
Plain thread	380	3.2	22.1	293	6.4	13.7
Waxed thread	359	7.5	19.5	344	8.7	11.3
No wrapping	352	6.5	19.0	335	7.8	19.4
Waxed union	175	10.9	17.1	298	13.1	18.1

TABLE XLII.—*Combined results for three years of experiments in wrapping root grafts.* (*Experiments 1 to 4.*)

Kind of wrapping.	Trees 1 year old.			Trees 2 years old.			Trees 3 years old.		
	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.	Number.	Galled.	Hairy.
		P. ct.	*P. ct.*		*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*
Cloth	705	9.8	4.4	1,737	7.3	5.9	759	2.9	3.1
Rubber	693	8.9	3.9	1,661	7.6	10.2	697	4.1	9.5
Waxed paper	668	26.0	5.0	1,550	9.3	11.0	666	5.4	11.4
Plain thread	652	21.5	10.7	1,566	9.6	14.9	672	6.6	12.6
Waxed thread	682	30.3	8.0	1,662	14.6	13.1	705	9.5	11.6
No wrapping	535	39.6	9.0	1,504	12.4	16.5	563	8.4	11.5
Waxed union	379	48.8	6.6	938	21.5	14.1	341	12.6	13.5

TABLE XLIII.—*Final summary of results of experiments 1 to 4 in wrapping root grafts.*

Kind of wrapping.	Healthy trees.	Galled trees.	Hairy-rooted trees.
	Number.	*Per cent.*	*Per cent.*
Cloth	2,814	6.8	5.3
Rubber	2,571	7.1	8.6
Waxed paper	2,251	12.3	9.7
Waxed thread	2,178	16.9	11.7
Plain thread	2,168	11.6	13.4
No wrapping	1,784	17.2	14.3
Wax covered	1,025	26.0	12.2
Total	14,791		

TABLE XLIV.—*Results of experiments in washing apple scions and roots in a 2 per cent copper-sulphate solution.*

Variety.	Trees grown from untreated stock.			Trees grown from stock treated with copper sulphate.		
	Smooth.	Galled.	Hairy.	Smooth.	Galled.	Hairy.
Wealthy	115	121	23	49	27	3
Northern Spy	57	8	9	33	1	4
Gano	77	2	48	40	2	14
Total	249	131	80	122	30	21
Per cent	54.1	25.5	17.8	70.5	17.4	12.1

INDEX TO LITERATURE.

1. Alwood, William B. Crown-gall. Third Report of the State Entomologist, Virginia, 1901, 33 pp. and 10 pls.
2. ——— Some observations on crown-gall of apple trees. Bulletin 140, Va. Agr. Expt. Sta., 1902, pp. 187–212 and 10 figs.
3. ——— Injurious insects and plant diseases. Special Bulletin 45, Va. Agr. Expt. Sta., Aug., 1904, pp. 17–20 and figs. 19–22.
4. ——— Apple crown-gall. Rept., Md. State Hort. Soc., vol. 7, 1905, p. 114.
5. Bailey, L. H. Root galls. Bulletin 117, N. Y. (Cornell) Agr. Expt. Sta., 1896, pp. 367–375 and fig. 131; also Ninth Annual Report of same station, 1897, pp. 425–434.
6. Beach, S. A., Lowe, V. H., and Stewart, F. C. Common diseases and insects injurious to fruits. Bulletin 176, N. Y. (Geneva) Agr. Expt. Sta., 1899, pp. 417, 418, and 439.
7. Butz, George C. Crown-gall. Rept., Pa. State College, 1901–1902, pp. 405–412 and 1 pl., 1902.
8. Clinton, G. P. Report of the botanist. Crown-gall. Rept., Conn. Agr. Expt. Sta., 1904, pp. 299, 309, 338, 346, and 354 and pl. 24.
9. Dodge, G. M. Root-knot on apple trees. Insect Life, vol. 2, 1890, p. 315.
10. Forbes, S. A. The crown-gall as a nursery pest. Trans., Ill. State Hort. Soc., vol. 34, 1900, pp. 136–150 and pls. 1–4.
11. ——— Entomological notes and inspection report for 1901. The crown-gall. Trans., Ill. State Hort. Soc., vol. 35, 1902, pp. 150–154.
12. ——— The crown-gall. Report of the State Entomologist, Illinois, vol. 22, 1903, pp. 108–110 and 1 pl.
13. ——— Report of inspection and insecticide operations. Crown-gall in nurseries. Trans., Ill. State Hort. Soc., vol. 37, 1904, pp. 229–232.
14. Frank, A. B. Die Krankheiten der Pflanzen, vol. 3, 1896, pp. 316–318.
15. Garman, H. Diseases of nursery stock. Crown-gall. Bulletin 93, Ky. Agr. Expt. Sta., 1901, pp. 104–106 and figs. 1–3.
16. ——— Diseases of nursery stock. A knot disease of apple trees. Bulletin 93, Ky. Agr. Expt. Sta., 1901, pp. 106–107 and fig. 4.
17. Guilford, W. H. Root-galls. Rept., Iowa State Hort. Soc., vol. 36, 1902, p. 525.
18. Hedgcock, George G. Some of the results of three years' experiments with crown-gall. Science, n. s., vol. 22, 1905, pp. 120–121; also National Nurseryman, vol. 13, Aug., 1905, p. 129; also American fruits, vol. 3, 1905, p. 75.
19. ——— The crown-gall and hairy-root diseases of the apple tree. Bulletin 90, pt. 2, Bureau of Plant Industry, U. S. Dept. of Agriculture, Nov., 1905, 7 pp. and 3 pls.
20. ——— The crown-gall and hairy-root diseases of the apple tree. Rept., Va. State Hort. Soc., vol. 10, 1906, pp. 152–155.
21. ——— Prevention of apple crown-gall and hairy-root. National Nurseryman, vol. 15, 1907, pp. 192–193; also American Fruits, vol. 7, 1907, p. 69.

22. Hedgcock, George G. The cross-inoculation of fruit trees and shrubs wi crown-gall. Bulletin 131, pt. 3, Bureau of Plant Industry, U. S. Dept. Agriculture, Mar., 1908, pp. 21-23.

23. ——— Some stem tumors or knots on apple and quince trees. Circular Bureau of Plant Industry, U. S. Dept. of Agriculture, May, 1908, 16 pp. a 10 figs.

24. Howard, W. L. Experiments with crown-gall. Rept., Mo. State Hort. Soc. vol. 46, 1903, pp. 154-159; also Western Fruit Grower, vol. 14, 1904, pp. 112-11 and 5 figs.

25. Hendrick, H. F. Orchard pests. Bulletin 55, Utah Agr. Expt. Sta., 1898, pp 157-168.

26. Isaac, J. Crown-gall. Rept., Cal. State Board Hort., vol. 8, 1902, pp. 77-80.

27. Jacobs. Root-knot. Rept., Cal. State Board Hort., vol. 4, 1894, p. 153.

28. Jaeger Julie. Ueber Kropfmaserbildung am Apfelbaum. Zeitschrift f Pflanzenkrankheiten, vol. 18, 1908, pp. 257-272 and pl. 7.

29. Johnson, W. G. Crown-gall. National Nurseryman, vol. 9, July, 1903, pp. 68-69.

30. Kissa, N. W. Kropfmaserbildung bei Pirus malus sinensis. Zeitschrift für Pflanzenkrankheiten, vol. 10, 1900, pp. 129-132 and pls. 3 and 4.

31. Lelong, B. M. Root-knot. Rept., Cal. State Board Hort., vol. 4, 1894, p. 313.

32. Miles, George F. Diseases of the apple tree and fruit. Crown-gall. Rept., Nebr. State Hort. Soc., vol. 34, 1903, p. 58.

33. Morris, O. M. Rept., Okla. Agr. Expt. Sta., vol. 14, 1905, p. 21.

34. Norton, J. B. S. Plant diseases in Maryland in 1902. Rept., Md. State Hort. Soc., vol. 5, 1902, pp. 92-93.

35. ——— Crown-gall. Circular Bulletin 42, Md. Agr. Expt. Sta., Mar., 1902, p. 18 and fig. 10.

36. ——— Crown-gall. Circular Bulletin 51, Md. Agr. Expt. Sta., Mar., 1903, pp. 1-3 and fig. 1.

37. ———. Crown-gall. Circular Bulletin 56, Md. Agr. Expt. Sta., Apr. and May, 1904, pp. 1-8 and pls. 1-5.

38. Paddock, Wendell. Crown-gall. Bulletin 86, Colo. Agr. Expt. Sta., Dec., 1903, 7 pp. and 2 pls.

39. Pammel, L. H. The crown-gall disease. Iowa State Register and Farmer, No. 2713, May 10, 1907, p. 4.

40. Phillips, J. L. Report of committee on injurious fungi. Crown-gall. Rept., Va. State Hort. Soc., vol. 6, 1902, pp. 145-148 and fig. 7.

41. ——— Distinguish between hairy or fibrous root gall and hard root gall. National Nurseryman, vol. 13, Sept., 1905, pp. 144-145 and fig. 1.

42. ——— Recent observations on crown-gall of apple. Special Circular to Virginia Nurserymen, Jan., 1907, 4 pp.

43. ——— Crown-gall of the apple—the scion largely responsible. National Nurseryman, vol. 25, Aug., 1907, p. 224.

44. Popenoe, E. A. The crown-gall in Kansas. Rept., Kans. State Hort. Soc., vol. 27, 1903, pp. 134-137.

45. ——— Note on crown-gall. Western Fruit Grower, vol. 15, Jan., 1904, p. 25.

46. Pugsley, C. W. Diseases of the apple. Crown-gall. Rept., Nebr. State Hort. Soc., vol. 36, 1905, pp. 241-242.

47. Ritzema-Bos, J. Wurzelkropf. Zeitschrift für Pflanzenkrankheiten, vol. 4, 1894, p. 97.

48. Sandsten, E. P. Crown-gall. Rept., Wis. State Hort. Soc., vol 34, 1904, pp. 132-137.

SELBY, A. D. Root and stem galls. Proc., Columbus Hort. Soc , Ohio, vol 10, 1896, p. 141 and pl. 1.

——— Some diseases of orchard and garden fruits. Bulletin 79, Ohio Agr. Expt. Sta., 1897, p. 127 and fig. 7.

——— Preliminary report upon diseases of the peach. Bulletin 92, Ohio Agr. Expt. Sta., 1898, p. 214.

——— A condensed handbook of the diseases of cultivated plants in Ohio. Bulletin 121, Ohio Agr. Expt. Sta., 1900, p. 13 and fig. 11.

SMITH, ERWIN F. Stem and root tumors. Journal of Mycology, vol. 7, 1892, pp. 93 and 376.

——— and TOWNSEND, C. O. A plant tumor of bacterial origin. Science, n. s., vol. 25, Apr., 1907, pp. 671–673.

SMITH, R. E. Plant diseases of California. Crown-gall. Report of the plant pathologist. Bulletin 184, Cal. Agr. Expt. Sta., July, 1906, p. 247.

SMITH, W. E. Root galls. California Fruit Grower, vol 12, Dec., 1894, p. 481.

SORAUER, P. Kropfmaser. Handbuch der Pflanzenkrankheiten, vol. 1, 1886, pp. 731–734 and fig. 38.

——— Wurzelkropf. Handbuch der Pflanzenkrankheiten, vol. 1, 1886, pp. 737–743 and figs. 40 and 41.

——— Wurzelkropf. Die Schäden der einheimischen Kulturpflanzen durch tierische und pflanzliche Schmarotzer sowie durch andere Einflüsse, 1888, pp. 117–118.

——— Schutz der Obstbäume gegen Krankheiten. Wurzelkropf, pp. 58–60; Kropfmaser, pp. 58, 139–140, 1900.

——— Kropfmasern der Bäume. Handbuch der Pflanzenkrankheiten, vol. 1, 3d ed., 1908, pp. 378–386 and fig. 58.

STEWART, F. C. Plant diseases. Rept., Western N. Y. Hort. Soc., vol. 46, 1901, p. 85.

——— and BLODGETT, F. G. A fruit disease survey of the Hudson Valley in 1899. Bulletin 167, N. Y. (Geneva) Agr. Expt. Sta., 1899, pp. 298–299 and 304–305 and 1 pl.

——— ROLFS, F. M., and HALL, F. H. A fruit disease survey of western New York in 1900. Bulletin 191, N. Y. (Geneva) Agr. Expt. Sta., 1900, pp. 300–301 and pl. 2; also Rept., N. Y. (Geneva) Agr. Expt. Sta., 1901, pp. 176–178 and pl. 23.

5. TAFT, L. R. Crown-gall. Rept., Mich. Agr. Expt. Sta., for 1896, pp. 96–97, 1897.

6. ——— Crown-gall. Bulletin 156, Mich. Agr. Expt. Sta., 1898, pp. 305–306.

7. TARNANI, J. Ueber Vorkommen von Heterodera Schachtii Schmidt und H. radicicola Müll. in Russland. Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten, vol. 4, pt. 2, 1898, pp. 87–98.

8. TOUMEY, J. W. An inquiry into the cause and the nature of crown-gall. Bulletin 33, Ariz. Agr. Expt. Sta., 1900, pp. 29–30.

0. VAN DEMAN, H. E. Treatment of insects and fungous diseases. Rept., Va. State Agr. Soc., vol. 7, 1903, pp. 86–91.

1. VON SCHRENK, HERMANN. Crown-gall. Western Fruit Grower, vol. 13, Mar., 1903, p. 111.

2. ——— and HEDGCOCK, GEORGE G. The wrapping of apple grafts and its relation to the crown-gall disease. Bulletin 100, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1906, pp. 13–20.

73. ——— ——— Crown-gall and hairy-root diseases of the apple tree. Rept., Mo. State Hort. Soc., vol. 49, 1907, pp. 252–253; also The Fruit Grower, vol. 18, Jan., 1907, p. 38.

74. Wakker, J. H. Contributions à la pathologie végétale; les renflements des branches de quelques espèces de Ribes. Archives Néerlandaises des Sciences exactes et naturelles, vol. 23, 1889, pp. 396–400.
75. Whiting, C. A. Crown-gall in the nursery. National Nurseryman, vol. 9, Apr., 1901, p. 172.
76. Wilcox, E. Mead. Diseases of the apple, peach, pear, and plum, with methods of treatment. Bulletin 132, Ala. Agr. Expt. Sta., 1906, pp. 94–95 and 113–11 and figs. 11–16.
77. Woodworth, C. W., and Wickson, E. J. Bulletin 99, Cal. Agr. Expt. Sta., Dec., 1892, pp. 1–4.
78. ——— Root-knots on fruit trees and vines. Rept., Cal. Agr. Expt Sta., 1892–1894, pp. 436–440, 1894.
79. Woodworth, C. W. Crown-knot. Rept., Cal. Agr. Expt. Sta., 1894–1895, pp. 231–232, 1896.
80. Yates, W. A. Root galls. California Fruit Grower, vol. 13, Feb., 1895, p. 111.
81. ——— Some remarks on root or stem tumors. Bulletin 39, Tex. Agr. Expt. Sta., 1896, pp. 842–843.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* Fig 1.—A 2-year-old York Imperial apple tree diseased with the hard form of crown-gall. This tree was planted in orchard 1 and is typical of the most seriously diseased trees planted in the experimental orchards. Fig. 2.—A 2-year-old Ben Davis apple tree diseased with the woolly-knot form of hairy-root. This tree was planted in orchard 4 and is typical of many of the trees in this orchard.

PLATE II. Fig. 1.—Two seedling apple trees diseased with the soft form of crown-gall. These were graft-inoculated with pieces of live soft crown-galls from the roots of rose bushes before they were planted out. Fig. 2.—Two seedling apple trees diseased as those in figure 1, except that they were inoculated with pieces of live soft galls from the roots of raspberry plants. Fig. 3.—Two yearling Wealthy apple trees diseased with the hard form of crown-gall. These trees were grown from root grafts, and the galls formed on the scion portion of the trees above the union of the scion and root pieces. Fig. 4.—A 2-year-old root-grafted York Imperial apple tree diseased with the hard form of crown-gall on the lower end of the scion. Fig. 5.—The same form of disease as that shown in figures 1 and 2 on a 2-year-old Wealthy apple tree in which the gall surrounds the union.

PLATE III. Fig. 1.—Yearling apple tree diseased with the simple form of hairy-root. These are typical of the seedlings used in the experiments with this form of the disease. Fig. 2.—A 2-year-old Jonathan apple tree diseased with the broom-rooted form of hairy-root, from cooperative plat 3. Fig. 3.—A healthy, smooth-rooted apple tree, typical of those planted in orchards 1 to 4. Fig. 4.—A healthy seedling apple tree with an excess of fibrous roots, but not a trace of either crown-gall or hairy root.

PLATE IV. Fig. 1.—An early stage of the aerial form of hairy-root at the base of a terminal bud on a Charlamoff apple-tree twig. Fig. 2.—Another portion of the same twig, showing the knot that formed during each of the preceding years at the base of the terminal bud. Fig. 3.—Early stage of the aerial form of hairy-root at the base of buds on a much larger limb of the same tree from which the twigs shown in figures 1 and 2 were taken.

PLATE V. Fig. 1.—Mature stage of the aerial form of hairy-root on a limb of a Winesap seedling apple tree. Fig. 2.—Another diseased limb of the same tree, showing a development of roots (woolly-knot) from some of the knots after the limb had been placed in a moist chamber for two weeks.

PLATE VI. Fig. 1.—A longitudinal section of a grafted apple tree through a soft crown-gall 2 months old, formed on the lower end of the scion of a poorly fitted root graft in an experiment. Fig. 2.—An early stage in the development of the simple form of hairy-root, showing the origin of roots from the base of buds on a yearling apple seedling when placed in moist sand in early springtime. Fig. 3.—A later stage in the development of the same form. Fig. 4.—An older stage of the simple form of hairy-root, showing how the small roots dry up and become hair-like. It was from this form that the disease received the name "hairy-root." Fig. 5.—A longitudinal section through a Wealthy apple tree diseased with the woolly-knot form of hairy-root. Both the tree and the knot are 2 years old, the latter originating in a wound, as indicated by the dark line in the tissues beneath the knot. Fig. 6.—A longitudinal section through a hard crown-gall on a 2-year-old Wealthy apple tree, showing the origin of the gall from the lower end of the scion.

PLATE VII. Fig. 1.—The root of a seedling apple tree grown from a cutting taken from a seedling apple tree diseased with the simple form of hairy-root. Fig. 2.—The root of a Charlamoff apple tree grown from a root graft, the scion of which was taken from a tree diseased with the aerial form of hairy-root. Both this and the former tree show only traces of the woolly-knot form of the disease and were exceptionally vigorous trees. Fig. 3.—Roots of a yearling Fameuse apple tree grown from a root graft made from a healthy scion united with a root piece diseased with the simple form of hairy-root. The scion has thrown out healthy roots. This is typical of the varieties of apple trees which root readily from the scion. Fig. 4.—Roots of a Jonathan apple tree grown similarly to the previous one. This tree has not thrown out roots from the scion and is typical of those varieties of apple trees which do not root readily from the scion.

ATE VIII. Fig. 1.—Apple root grafts, showing nine kinds of wrapping used in the experiments: *A*, Ordinary unwaxed thread; *B*, wrapped with thread, then coated with grafting wax; *C*, cloth wrapping, the outer end of the strip fastened down with grafting wax; *D*, ordinary waxed thread; *E*, thin sheet-rubber strip with the end cemented down; *F*, a graft without wrapping; *G*, waxed paper strip; *H*, raffia, completely covering the union; *I*, ordinary raffia wrapping. Fig. 2.—Root grafts showing excessive callus at the lower blunt end of the scions. This callus favors the entrance of the disease. When planted in an experiment in the greenhouse, these root grafts all developed crown-gall at the point of formation of callus.

ATE IX. Fig. 1.—The stump of an 8-year-old Collins apple tree grown in orchard 1. This tree, the largest in the orchard, was diseased with the woolly-knot form of hairy-root. Fig. 2.—Apple root grafts and seedlings used in the experiments: *A*, A hand-wrapped root graft; *B*, a machine-wrapped root graft; *C* and *D*, poorly fitted root grafts; *E* and *F*, healthy apple seedlings; *G* and *H*, apple seedlings diseased with hairy-root.

LATE X. Two rows of Collins apple trees in orchard 1 at the age of 8 years: *A*, This row was diseased with the hard form of crown-gall when set in the orchard; *B*, this row was healthy when set in the orchard and remained comparatively so until the end of the experiment.

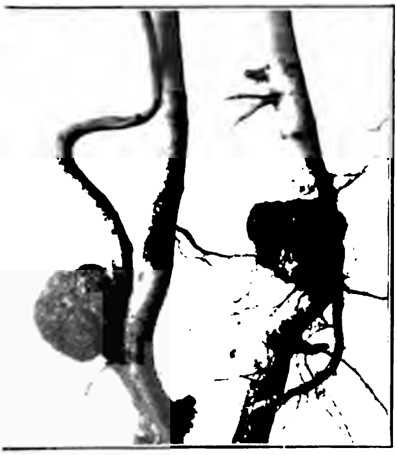


FIG. 1.—SOFT FORM OF CROWN-GALL OF THE APPLE, FROM INOCULATION WITH ROSE GALLS.

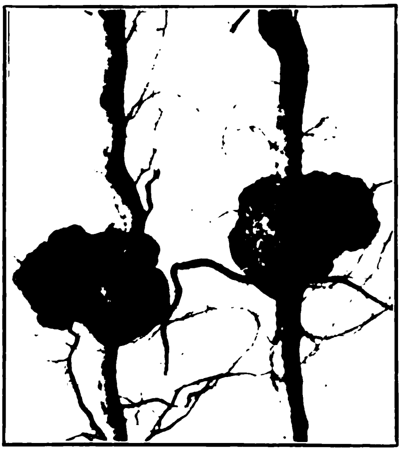


FIG. 2.—SOFT FORM OF CROWN-GALL OF THE APPLE, FROM INOCULATION WITH RASPBERRY GALLS.

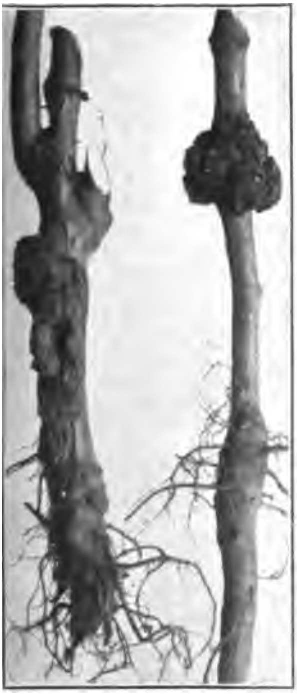


FIG. 3.—HARD FORM OF CROWN-GALL ON THE SCION PORTION OF ROOT-GRAFTED APPLE TREES.

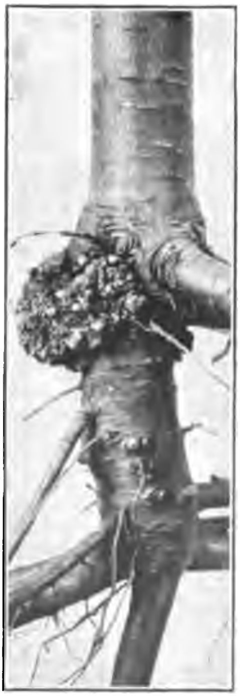


FIG. 4.—HARD FORM OF CROWN-GALL AT THE LOWER END OF THE SCION IN A ROOT-GRAFTED APPLE TREE.

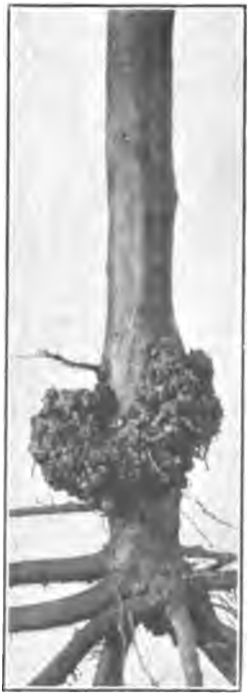
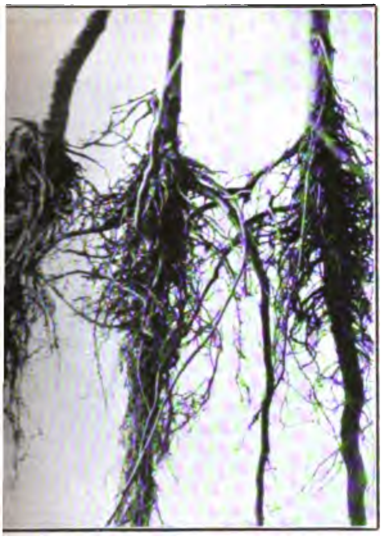


FIG. 5.—HARD FORM OF CROWN-GALL SURROUNDING THE UNION IN A ROOT-GRAFTED APPLE TREE.



G. 1.—SIMPLE FORM OF HAIRY-ROOT ON APPLE SEEDLINGS, TYPICAL OF THOSE USED IN THE EXPERIMENTS.

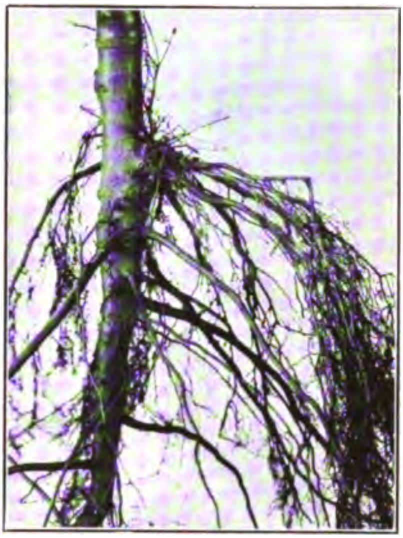


FIG. 2.—BROOM-ROOT FORM OF HAIRY-ROOT ON A 2-YEAR-OLD APPLE TREE.

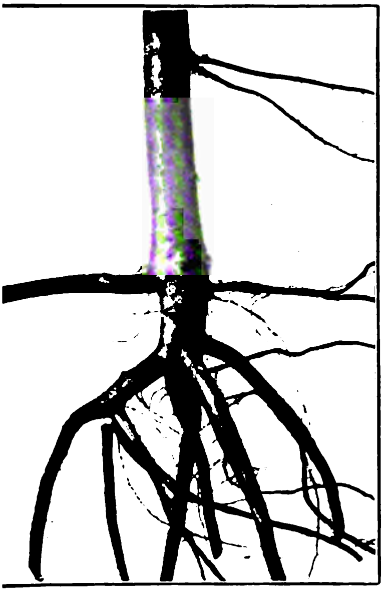


FIG. 3.—HEALTHY ROOT-GRAFTED APPLE TREE, SHOWING THE TYPE OF THE HEALTHY TREES PLANTED IN THE EXPERIMENTAL ORCHARDS.

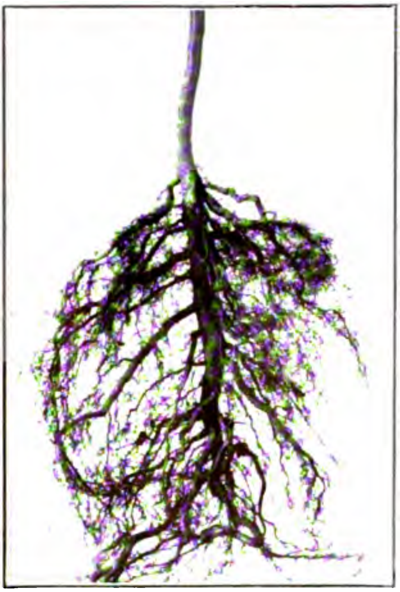


FIG. 4.—HEALTHY SEEDLING APPLE TREE WITH FIBROUS ROOTS.

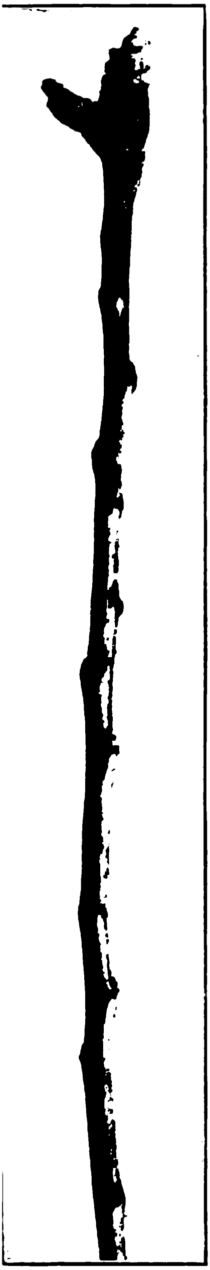


FIG. 1.—EARLY STAGE OF THE AERIAL FORM OF HAIRY-ROOT ON AN APPLE TWIG.

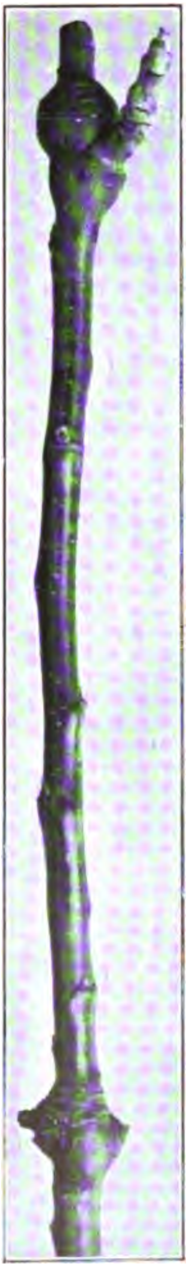


FIG. 2.—LATER STAGE OF THE AERIAL FORM OF HAIRY-ROOT ON THE SAME TWIG AS THAT SHOWN IN FIGURE 1.

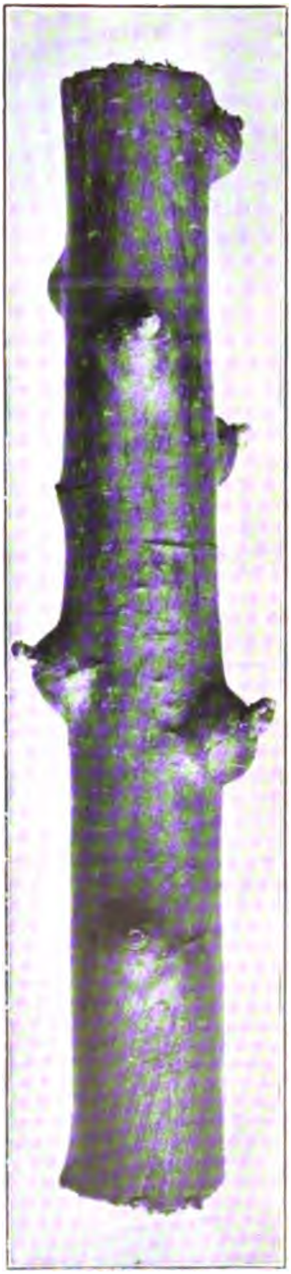


FIG. 3.—EARLY STAGE OF THE AERIAL FORM OF HAIRY-ROOT ON AN OLDER LIMB OF THE SAME TREE AS THAT FROM WHICH THE TWIGS SHOWN IN FIGURES 1 AND 2 WERE TAKEN.

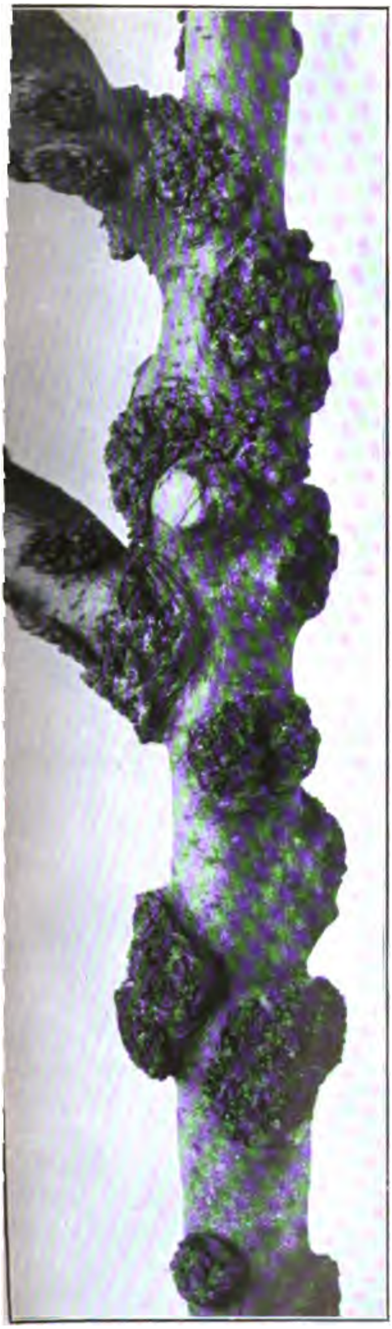


FIG. 1.—MATURE STAGE OF THE AERIAL FORM OF HAIRY-ROOT ON A WINESAP SEEDLING APPLE TREE.

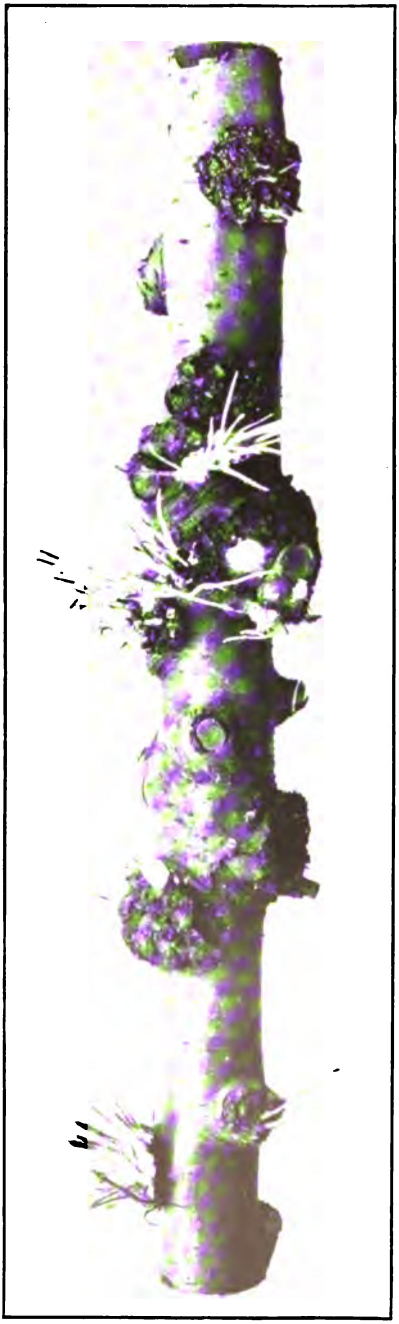
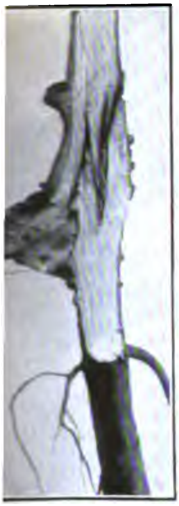


FIG. 2.—ROOT PRODUCTION FROM THE AERIAL FORM OF HAIRY-ROOT ON A LIMB FROM THE SAME TREE AS THAT FROM WHICH THE LIMB SHOWN IN FIGURE 1 WAS TAKEN.



. 1.—Radial Section through a Soft Crown-Gall n an Apple Root Graft.

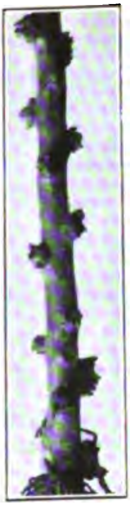


Fig. 2.—Early Stage of the Simple Form of Hairy-Root on an Apple Seedling.

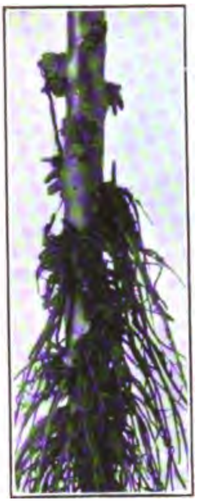


Fig. 3.—A Later Stage in the Development of the Same Form as that Shown in Figure 2.

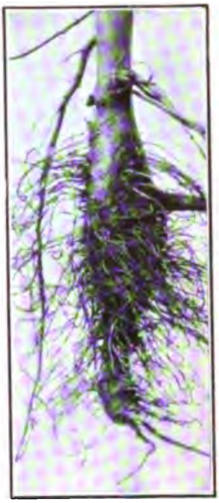


Fig. 4.—An Older Stage of the Simple Form of Hairy-Root, Many Roots Being Hair-like.

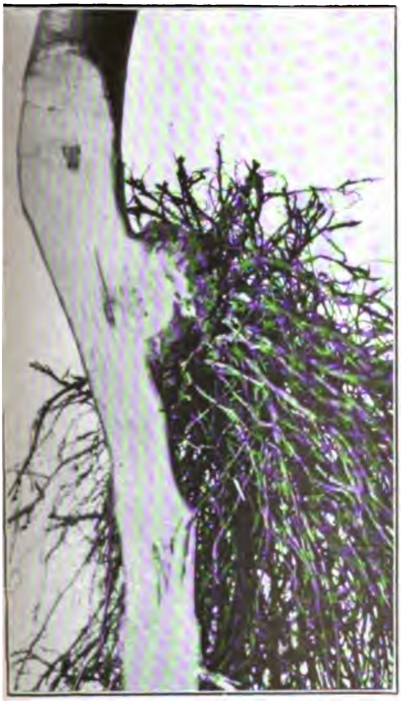


Fig. 5.—Radial Section through a Woolly Knot Originating in a Wound on the Scion of a Root-Grafted Apple Tree.

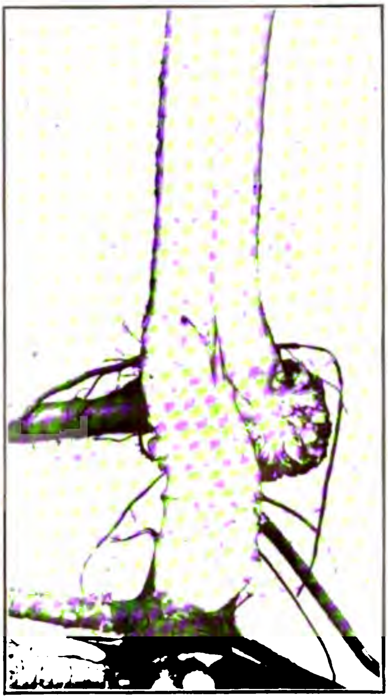
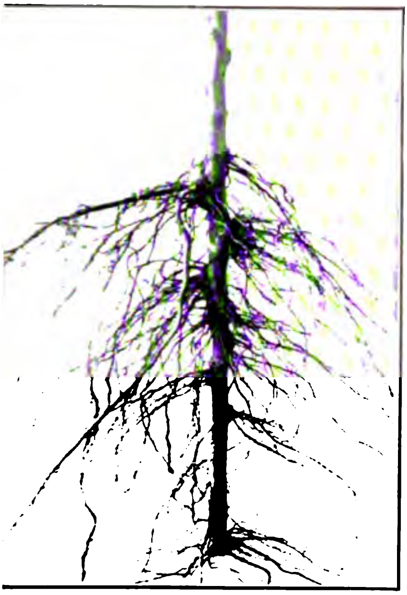


Fig. 6.—Radial Section through a Hard Crown-Gall Originating on the Lower End of the Scion of a Root-Grafted Apple Tree.



IG. 1.—ROOT OF AN APPLE TREE GROWN FROM A CUTTING TAKEN FROM A SEEDLING APPLE TREE DISEASED WITH THE SIMPLE FORM OF HAIRY-ROOT.

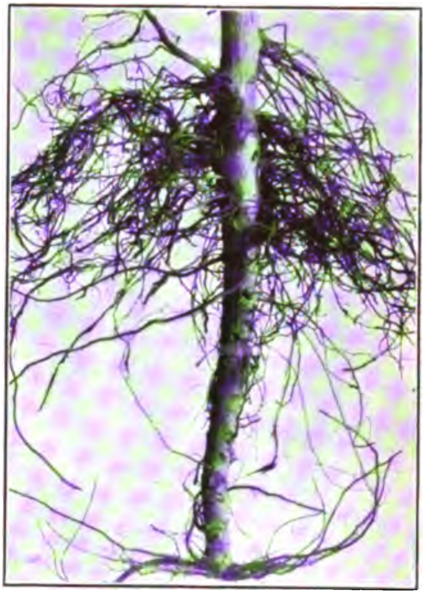


FIG. 2.—ROOT OF A GRAFTED APPLE TREE GROWN FROM A SCION TAKEN FROM A DISEASED LIMB OF THE TREE TWIGS AND A LIMB OF WHICH ARE SHOWN IN PLATE IV.

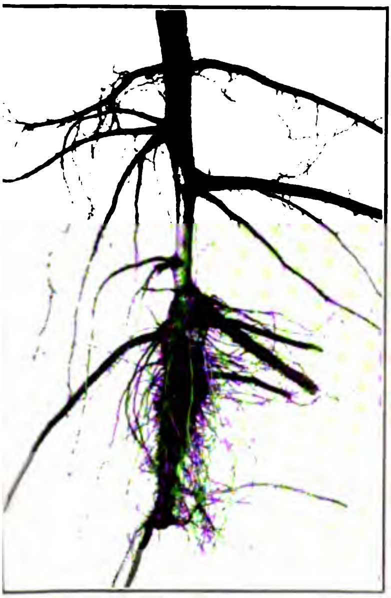


FIG. 3.—ROOTS OF A FAMEUSE APPLE TREE GROWN FROM A ROOT GRAFT WITH THE ROOT PIECE DISEASED WITH HAIRY-ROOT, BUT WITH HEALTHY ROOTS ON THE SCION.

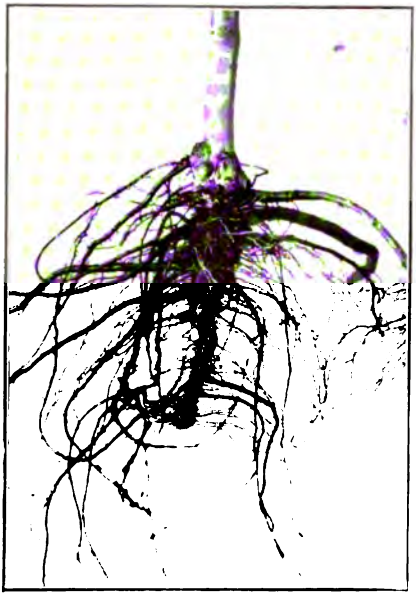


FIG. 4.—ROOTS OF A JONATHAN APPLE TREE GROWN FROM A ROOT GRAFT DISEASED WITH HAIRY-ROOT, BUT WITH NO ROOTS ON THE SCION.

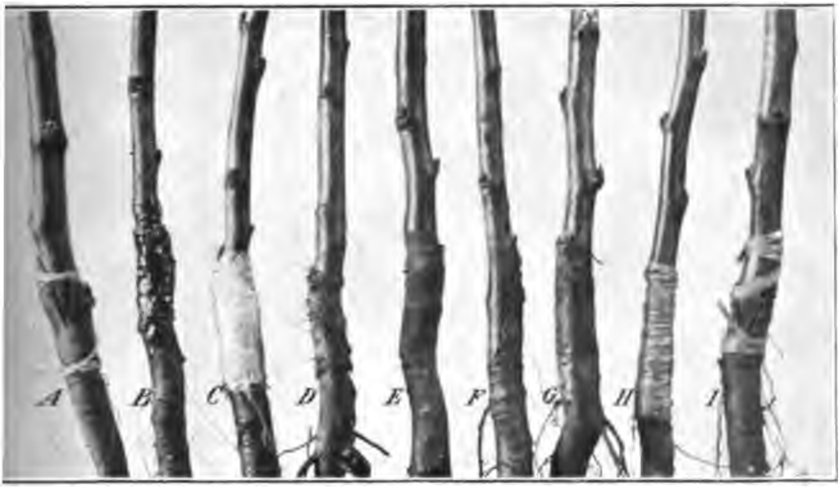


FIG. 1.—APPLE ROOT GRAFTS SHOWING NINE KINDS OF WRAPPING USED IN THE EXPERIMENTS.

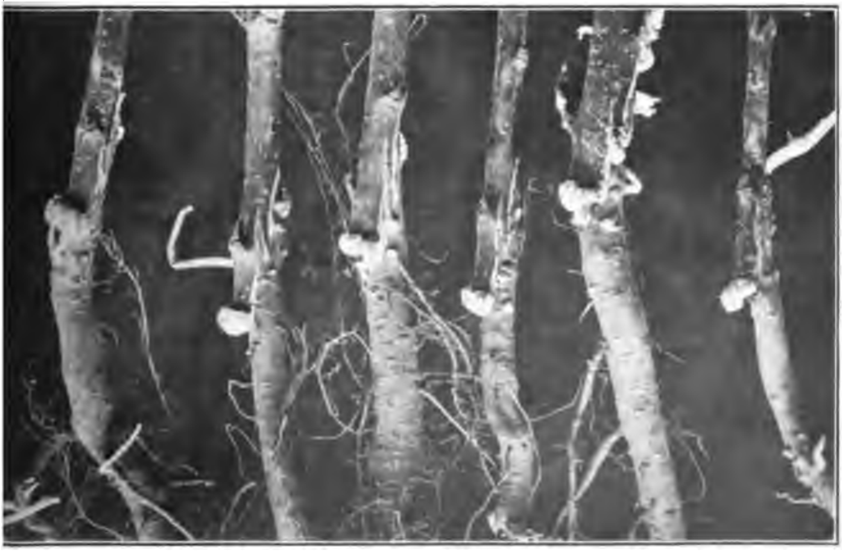
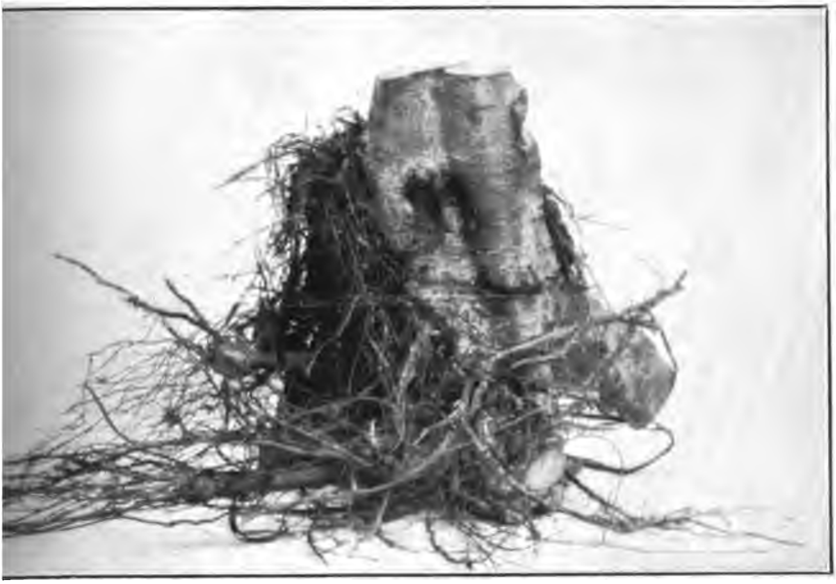


FIG. 2.—ROOT GRAFTS LEFT TOO LONG IN STORAGE, SHOWING EXCESSIVE DEVELOPMENT OF CALLUS. THE SCIONS WERE CUT WITH THE LOWER TIP BLUNT.



IG. 1.—THE WOOLLY-KNOT FORM OF HAIRY-ROOT ON THE CROWN OF A COLLINS APPLE TREE IN ORCHARD 1.

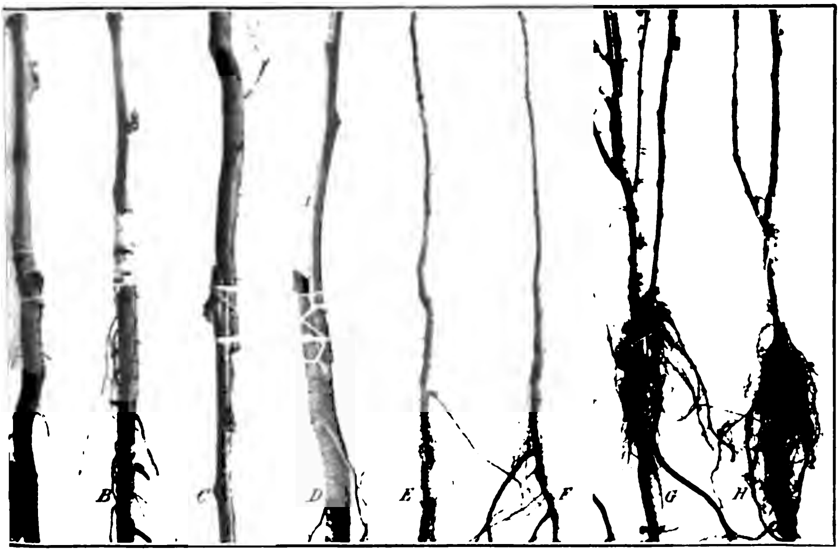
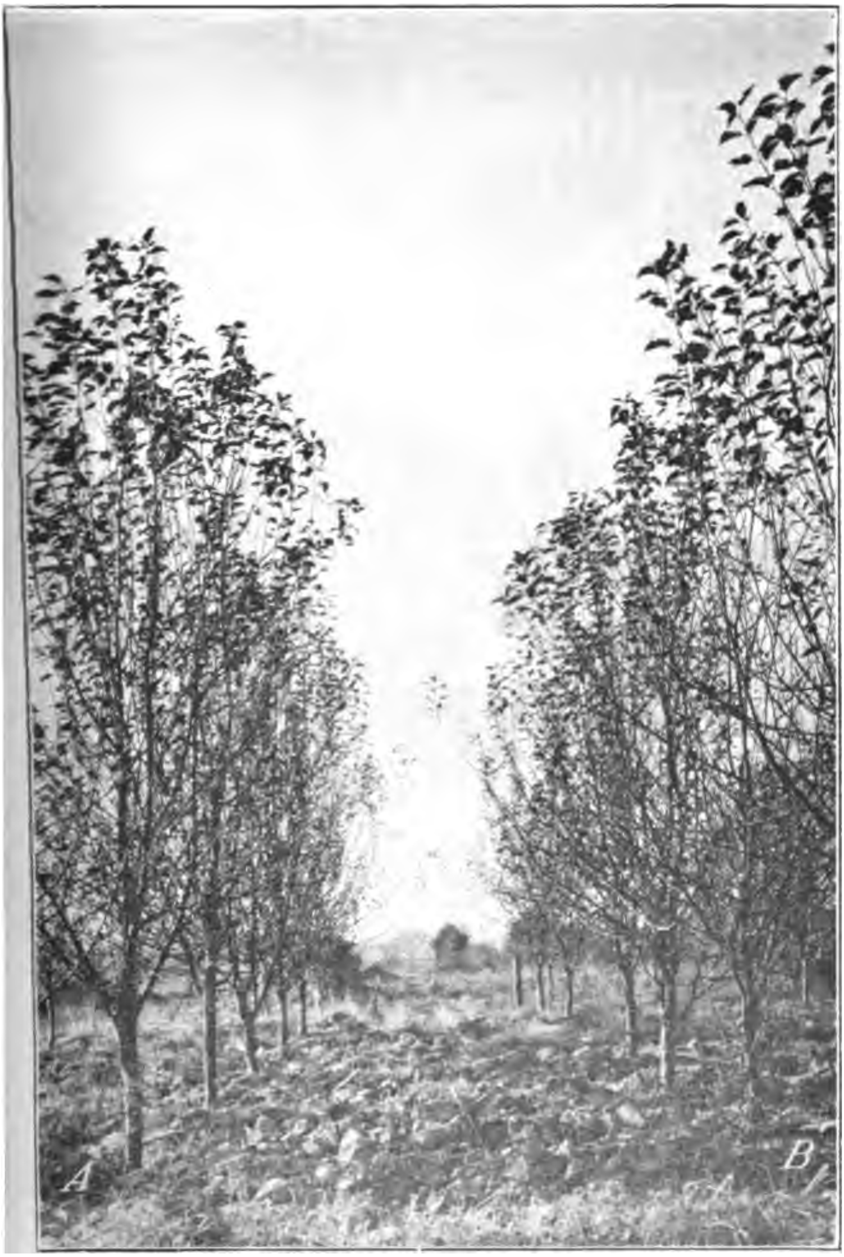


FIG. 2.—APPLE ROOT GRAFTS AND SEEDLINGS USED IN THE EXPERIMENTS.



TYPICAL ROWS OF TREES IN ORCHARD 1: *A*. A ROW OF COLLINS APPLE TREES DISEASED WITH THE HARD FORM OF CROWN-GALL WHEN PLANTED IN THE ORCHARD; *B*. A ROW OF THE SAME VARIETY, PLANTED AT THE SAME TIME, BUT WITH HEALTHY ROOTS.

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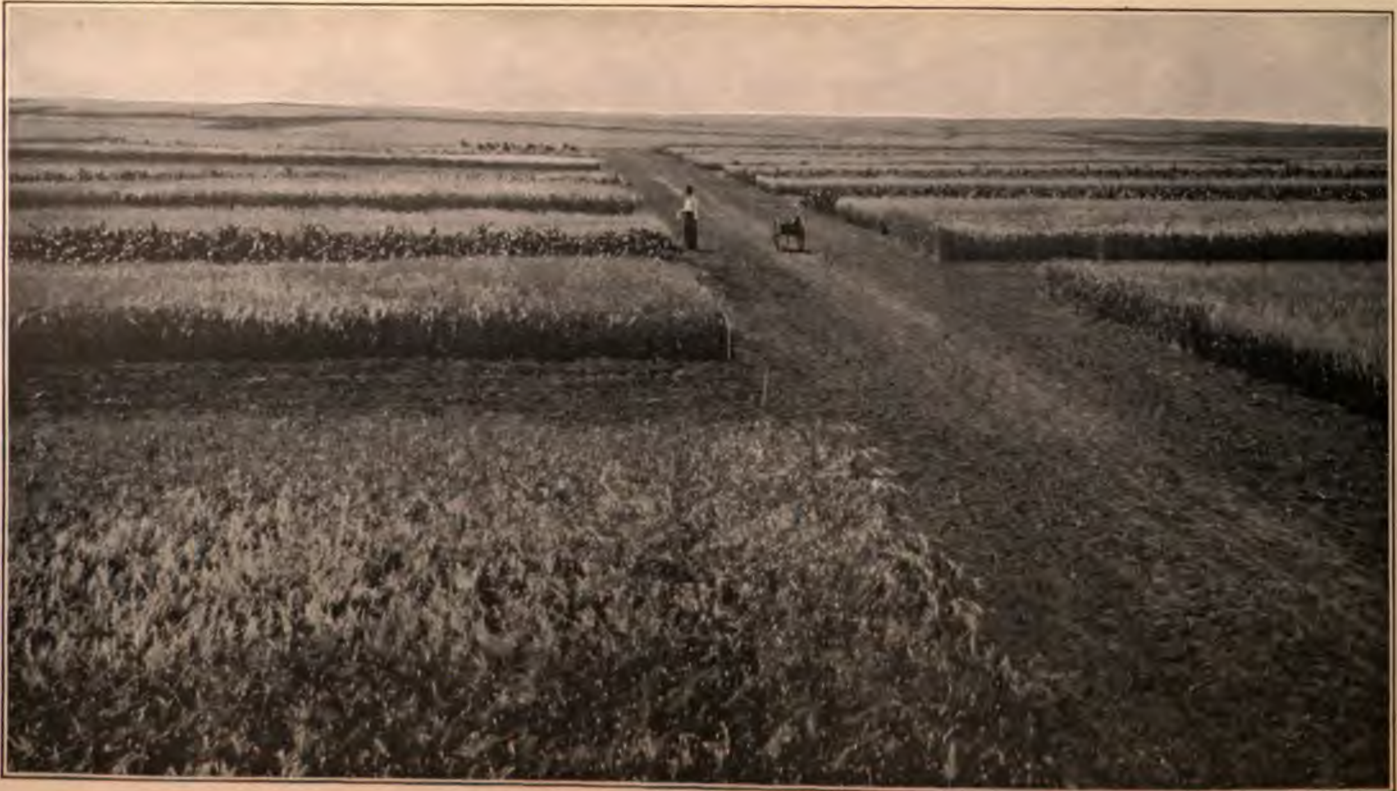

A TYPICAL VIEW OF EXPERIMENTAL FIELD PLATS.

(Photographed at the Substation at Edgeley, N. Dak., August 1, 1908, by Dr. H. L. Shantz.)

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 187.

B. T. GALLOWAY, *Chief of Bureau.*

NOV 18 1910

STUDY OF CULTIVATION METHODS AND CROP ROTATIONS FOR THE GREAT PLAINS AREA.

BY

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AGRICULTURIST IN CHARGE, ASSISTED BY MEMBERS OF THE
FIELD STAFF OF THE OFFICE OF DRY-LAND
AGRICULTURE INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 11, 1910.

R: I have the honor to transmit herewith a paper entitled "A
ly of Cultivation Methods and Crop Rotations for the Great
ns Area," by Prof. E. C. Chilcott, Agriculturist in Charge of Dry-
d Agriculture Investigations, assisted by the members of his field
Y. These men have not only attended to the details of the field
eriments and prepared the notes for the permanent records, but
y have also assisted in the preparation of these data for publication.

he paper embodies the results of four years' experiments in crop
ation and cultivation methods conducted at eleven stations in the
eat Plains area. These investigations are of such a nature as to
uire a long term of years before final conclusions can be reached.
is believed, however, that in view of the urgent demand for infor-
ation concerning these problems which is constantly being made
on this Bureau, these results and tentative conclusions and sugges-
ons should be made public at this time.

I recommend that this paper be published as Bulletin No. 187 of the
ecial series of this Bureau.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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PLATE I. A typical view of experimental field plats .... Frontispiece.

TEXT FIGURE.

FIG. 1. Map of the Great Plains area, showing the location of the experiment stations and the annual and seasonal rainfall 17

. P. I.—585.

A STUDY OF CULTIVATION METHODS AND CROP ROTATIONS FOR THE GREAT PLAINS AREA.

INTRODUCTION.

The Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry has been carrying on investigations in dry-land agriculture in the Great Plains area since the spring of 1906. A large amount of data has accumulated. Urgent demands are being made by settlers, actual and prospective, for information concerning the best methods of farming in the Great Plains. It therefore seems desirable at this time to give publicity to such of these facts and figures as have a direct bearing upon this subject. It is not claimed that sufficient data have yet been accumulated to form the basis for final conclusions. It is believed, however, that these results are of sufficient importance to deserve careful consideration and that they throw some strong light upon the much controverted questions of summer tillage, continuous cropping, and crop rotation. It is hoped that the tentative conclusions drawn and the suggestions made may be useful.

QUESTIONS ASKED.

These investigations were undertaken to answer the following main questions, besides many subsidiary ones:

(1) How can the largest average yields of four staple crops—corn, spring wheat, oats, and barley—through a long series of years be obtained: (*a*) By raising the same crop continuously by ordinary methods of culture now in practice; (*b*) by continuous cropping with the same crop, using the most approved methods of cultivation for moisture conservation; or (*c*) by alternate cropping and summer tillage by the most approved methods?

(2) Do moisture conservation methods pay where continuous cropping to the same crop is practiced?

(3) Do alternate cropping and summer tillage pay where the same crop is raised each alternate year?

(4) How do simple 3-year crop rotations compare with continuous cropping, both with and without conservation methods, and with alternate cropping and summer tillage in the profitable production of crops?

(5) What 3-year rotation has given the best results?

(6) Which gives the best results, fall plowing or spring plowing?

(7) Should corn stubble be plowed or disked without plowing as a preparation for spring wheat?

(8) Can summer tillage be profitably introduced into a rotation system?

(9) Can any system of crop rotation be devised, involving the use of perennial grasses or legumes, or biennial legumes, which will be adapted to conditions in the Great Plains area?

(10) Can green manuring be profitably substituted for summer tillage, thereby conserving both the moisture and the organic matter of the soil?

(11) What is the best method of introducing winter wheat into a rotation?

ANSWERS OBTAINED.

The following tentative answers have been obtained from the investigations. They are likely to be modified by future results. They are, however, based upon the best evidence obtainable in the present state of our knowledge:

(1) The average yields in bushels per acre from the three methods of tillage have been as follows:

Average production per acre of wheat, oats, and barley.

Methods of tillage.	Wheat.	Oats.	Barley.
Continuous cropping, ordinary methods	17.4	30.2	21.1
Continuous cropping, moisture conservation	16.5	28.5	22.9
Alternate cropping and summer tillage	22.5	44.1	30.7

(See Tables I, II, and III, pp. 16 and 17.)

(2) The average results of moisture conservation methods have not proved profitable as compared with ordinary methods where continuous cropping has been practiced. (See paragraph 2 of Conclusions, p. 68.)

(3) The average results of alternate cropping and summer tillage have not proved profitable, as compared with continuous cropping with ordinary methods. (See paragraph 1 of Conclusions, p. 67.)

(4) Simple 3-year rotations of corn, wheat, and oats, or corn, barley, and oats have proved more profitable than continuous cropping or alternate cropping with any one of these four crops. (See paragraph 3 of Conclusions, p. 68.)

(5) Corn on either fall or spring plowing, followed by either wheat or barley on disked corn stubble, followed by oats on early fall plowing has given best average results. (See paragraph 4 of Conclusions, p. 68.)

(6) Fall plowing has given slightly better average results than spring plowing. (See paragraph 11 of Conclusions, p. 69.)

(7) Disking corn stubble, without plowing, has given better results than plowing as a preparation for spring wheat. (See paragraph 10 of Conclusions, p. 69.)

(8) Summer tillage has not given as good average results when used in a rotation as a preparation for spring wheat or oats as has a properly cultivated corn crop. It seems probable that it will be found advisable to occasionally introduce summer tillage into a rotation as a preparation for winter wheat. (See paragraph 9 of Conclusions, p. 68.)

(9) The evidence so far obtained leads to the conclusion that a 5 or 6 year rotation of corn, winter or spring wheat, brome-grass (three years), oats, barley, emmer, or

wheat will give better average results than any other system so far tried. There are, however, undoubtedly many localities where the growing of perennial grasses is so uncertain as to make the adoption of this rotation inadvisable. It is possible that it may be found practicable to substitute alfalfa for brome-grass in some localities. Some other perennial grass or legume may be found that will prove adapted to the conditions in some parts of the Great Plains. In some localities it may be found practicable to shorten the rotation to four years and substitute red clover for the brome-grass. (See paragraphs 14, 15, and 16 of Conclusions, p. 70.)

(10) Where perennial grass or legumes can not be successfully grown, it will undoubtedly be found profitable to resort to green manuring. Winter rye has so far given the best results. Canada field peas and common sweet clover (*Melilotus alba*) have also given good results, but the fact that they do not reach a sufficient stage of growth to plow under before the end of the June rains is against them. On the other hand, being nitrogen gatherers they will undoubtedly produce a higher quality of organic matter in the soil than rye, although the quantity may be less. (See paragraph 18 of Conclusions, p. 70.)

(11) Winter wheat should be grown to a greater or less extent wherever it is found possible to do so, as it possesses some great advantages over spring wheat. It can be fitted into any rotation adapted to the Great Plains. In some localities it may prove profitable to summer till the land as a preparation for winter wheat, as it undoubtedly responds to this preparation to a much greater extent than do spring-sown grains. Green manuring may, however, be used instead of summer tillage. (See paragraph 10 of Conclusions, p. 69.)

As will be seen from the foregoing answers, our investigations lead strongly to the conclusion that the devising of systems of rotation adapted to local conditions is of greater importance than tillage methods. It is not to be inferred, however, that the subject of proper tillage can be safely neglected. Such is far from being the case. Tillage methods must be carefully studied and intelligently practiced. But both the study and the practice must be carried on in connection with crop rotation and with a view to bringing about the best possible physical and biological condition of the soil. In order to do this intelligently, the requirements of the crops to be grown, the local peculiarities of the soil, and the climate must be the main factors considered. No hard and fast rules can be established. Each farmer must study his soil, his climate, and his crop requirements, and must adopt such systems of tillage as experience and observation have shown to bring the desired results under the peculiar combinations of conditions which prevail at the time and place and are most likely to exist during the growing period of the crop. Nor should the ultimate effect upon the soil of any system of tillage be neglected. Favorable physical, chemical, and biological conditions of the soil should at least be maintained and, if possible, improved from year to year.

The establishment of a system of crop rotations presents many difficulties, particularly in a new country. Among these difficulties is the need of immediate cash returns from the crops grown. Wheat is not only the most staple cash crop, but on the basis of the prices which have prevailed for the last ten years and the average yields obtained in the Great Plains it has also been the most profitable when immediate cash returns alone have been considered. This has been a strong incentive to adopting a one-crop system of wheat grown continuously on the same land, year after year, with sometimes an occasional summer fallow to clean the land of weeds.

It must be admitted that this system has often brought in larger immediate cash returns than could be obtained from a simple diversification of crops. Mere diversification without any systematic rotation often means simply devoting a portion of the farm to the growing of some less profitable crop in the place of wheat. There is an advantage in growing several different kinds of crops, all of which are not as likely to suffer loss from either poor yields or low prices as would a single crop of any one kind. Such a system can not, however, be defended unless these substituted crops can be fed or otherwise disposed of in such a way as to bring more than the relative market prices, as compared with wheat, which have prevailed in the Great Plains for the last ten years. But our investigations have shown that with a properly planned rotation of corn, wheat, oats, and barley the average farm value per acre for all the crops will be greater than that obtained from growing wheat continuously. Such a system must, of course, involve proper methods of soil preparation, as well as rotation of crops. If in addition to the increased yields obtainable under a rotation system the coarse grains can be fed on the farm, the net profits from this system will be further increased. If by returning the manure produced from the coarse grain, fodder, and hay crops to the land the soil can be maintained in better chemical, physical, and biological condition, it will not only further increase the yields in favorable years, but will also decrease the danger from drought in unfavorable ones. Nor is this all the advantage to be gained from crop rotation and its concomitant feature of stock raising. Under such a system the labor of the farm is more evenly distributed throughout the year, thus requiring less expense for extra laborers at harvest time and better utilization of teams and tools. And last, and perhaps most important of all, is the fact that a farm operated on such a system affords greater incentives and opportunities for true home building. It is believed that all of these desirable objects can be attained by adopting systems of rotation adapted to local conditions. It can, therefore, be stated with a reasonable degree of certainty that crop rotation is the major factor in the great problem of dry-land agriculture in the Great Plains area, with cultivation methods as an important minor factor.

These investigations have been carried on at Judith Basin, Mont.; Dickinson and Edgeley, N. Dak.; Highmore and Bellefourche, S.

ak.; North Platte, Nebr.; Akron, Colo.; Hays and Garden City, ans.; Amarillo and Dalhart, Tex. The locations of these stations re shown on the accompanying map, figure 1. Results have been btained for three years from Edgeley and North Platte; for two ears from Amarillo, Highmore, and Dickinson; and for one year

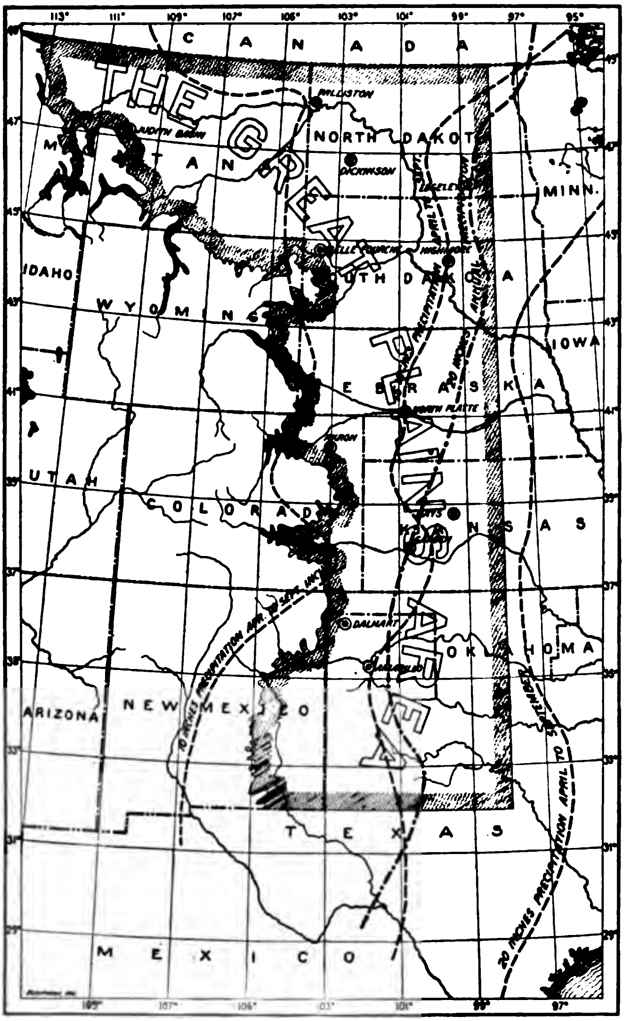

FIG. 1.—Map of the Great Plains area, showing the location of the experiment stations and the annual and seasonal rainfall.

each from the remaining stations. They show, therefore, the results of eighteen comparative tests, involving more than a thousand plats located at eleven stations widely distributed throughout the Great Plains area, and should be fairly representative of the area.

The view of field plats at the substation at Edgeley, N. Dak. (see frontispiece), where these investigations are carried on in cooperation with the North Dakota Agricultural Experiment Station, is typical of all the field stations. From 120 to 150 one-tenth acre plats are used at each station. These plats are accurately and permanently laid out and marked and great care is exercised to obtain exact yields, comparable to common field conditions.

It would be practically impossible to carry on these investigations without the hearty cooperation of the state experiment stations of Montana, North Dakota, Nebraska, and Kansas.

The Physical Laboratory and the Offices of Western Agricultural Extension, Alkali and Drought Resistant Plant-Breeding Investigations, Grain Investigations, Forage-Crop Investigations, and Soil-Bacteriology Investigations, all of the Bureau of Plant Industry, have cooperated and rendered valuable assistance along their respective lines. None of the results of their investigations have, however, been incorporated in this publication. The interrelation of these several lines of investigations with those of dry-land agriculture will be discussed in future publications.

THE SUFFICIENCY OF THE DATA SUBMITTED.

As the general plans of the investigations in dry-land agriculture, of which those herein described are a part, have been fully set forth in a previous publication,[a] no detailed description will here be attempted. Suffice it to say that a member of the scientific staff of this office is in constant attendance at each of the several stations mentioned during the entire growing and harvesting season. He attends personally to all the field operations, the measuring and weighing of products, etc., and keeps accurate notes of the work.[b] The work is in close cooperation with the Physical Laboratory of this

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[a] Yearbook of the Department of Agriculture for 1907, pp. 451–468.

[b] The field work at the several stations is under the immediate supervision, respectively, of the following-named members of the scientific staff of this office:

John S. Cole, Traveling Field Assistant.

J. E. Payne, Superintendent Akron, Colo., station.

F. L. Kennard, Superintendent Dalhart, Tex., station.

J. M. Stephens, Superintendent Judith Basin, Mont., station.

O. J. Grace, Acting Superintendent Dickinson, N. Dak., station.

W. W. Burr, detailed to North Platte, Nebr., station.

E. F. Chilcott, detailed to Amarillo, Tex., station.

A. L. Hallsted, detailed to Hays, Kans., station.

H. R. Reed, detailed to Garden City, Kans., station.

O. R. Mathews, detailed from the Office of Western Agricultural Extension, Bureau of Plant Industry, to Bellefourche, S. Dak., station.

C. H. Plath, detailed to Edgeley, N. Dak., station.

J. C. Thysell, detailed to Dickinson, N. Dak., station.

W. O. Whitcomb, detailed from the Office of Western Agricultural Extension, Bureau of Plant Industry, to Williston, N. Dak., station.

Bureau, which keeps a record of the physical and meteorological onditions at each station. Several other offices of this Bureau are lso in cooperation at most of the stations. The Agriculturist in Charge of Dry-Land Agriculture Investigations and his traveling field ssistant make frequent visits to the field stations during the growing eason for the purpose of inspecting the work. Other cooperating heads of offices also visit these stations at frequent intervals.

The work of seven of the eleven stations herein mentioned was conducted in close cooperation with the state experiment stations of Monana, North and South Dakota, Nebraska, and Kansas, respectively, and representatives of these stations are constantly in close touch with he field work at their respective localities. Very full permanent records of all the work are kept, both at the field stations and at the central office at Washington, D. C. Both these records and the field work itself are open to the inspection of the public at all times, and such nspection is invited. The experiment stations mentioned use these records in the preparation of publications of their respective stations. With so many trained investigators actively interested in the elimination of all sources of error or inaccuracy, it seems reasonable to claim that the data herein presented are trustworthy and that, covering as they do so extensive an area, they constitute as reliable a basis for safe conclusion concerning the methods of dry-land agriculture in the Great Plains area as can now be found. It is only by a further extension of these investigations that a more reliable basis can be established.

All of the eleven stations from which the data are collected are located within what is generally known as the semiarid area. The meteorological records and the crop yields under ordinary methods indicate, however, that in thirteen seasons out of eighteen the weather conditions were sufficiently favorable to give some basis for the suspicion that these thirteen experiments were conducted under humid rather than semiarid conditions and that they could not therefore be used as a safe basis for conclusions relative to semiarid conditions. When, however, we consider that the average increase in yields from summer tillage as compared with ordinary methods during these thirteen seasons is practically identical for oats and barley and differs by only 2.2 bushels for wheat from those of the remaining five seasons when the drought was severe, the force of this argument is considerably weakened. If we also consider that the only instance where summer tillage increased the yield sufficiently to make the practice profitable was at North Platte in 1908, where conditions were very favorable for crop production under ordinary methods, the argument against the applicability of these results to semiarid conditions ceases to have any weight.[a]

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[a] See Table XXXI for precipitation record.

CONTINUOUS CROPPING COMPARED WITH ALTERNATE CROPPING AND SUMMER TILLAGE.

GENERAL STATEMENT.

Before entering into a discussion of the subject of continuous cropping compared with alternate cropping and summer tillage, it will be well to clearly set forth some important considerations that must be constantly borne in mind. They are as follows:

(1) The discussion applies to the Great Plains area only and can have no possible bearing upon practices in regions west of the Rocky Mountains, where soil and climatic conditions are radically different.

(2) These experiments were made with spring-sown grains only and have no bearing whatever upon the methods applicable to fall-sown grains.

(3) The object of the work described under this heading is to test the relative merits of three systems of one-crop farming, namely, (1) ordinary methods; (2) moisture-conservation methods of continuous cropping; and (3) summer-tillage methods of alternate or biennial cropping. This part of the work has nothing whatever to do with crop rotation, except possibly to show that no system of one-crop farming has yet been devised that can serve as a safe basis for a permanent agriculture in the Great Plains area. A discussion of crop rotation is given under another heading (p. 20).

The general plan of that portion of the investigations herein described is identical for all of the eleven stations and is as shown in the accompanying outline and the explanatory notes following:

Outline of plan for experiments with three staple cereal crops with ordinary methods of culture and with moisture-conservation methods, each crop being grown on the same plat for several years either continuously or alternating with summer fallow.

EXPERIMENTS WITH WHEAT.

Plat A. Wheat grown year after year on spring-plowed land by ordinary methods of culture.
Plat B. Wheat grown year after year on fall-plowed land by moisture-conservation methods of culture.
Plat C. Wheat alternating with summer tillage.
Plat D. Summer tillage alternating with wheat.

EXPERIMENTS WITH OATS.

Plat A. Oats grown year after year on spring-plowed land by ordinary methods of culture.
Plat B. Oats grown year after year on fall-plowed land by moisture-conservation methods of culture.
Plat C. Oats alternating with summer tillage.
Plat D. Summer tillage alternating with oats.

EXPERIMENTS WITH BARLEY.

t A. Barley grown year after year on spring-plowed land by ordinary methods of culture.
t B. Barley grown year after year on fall-plowed ground by moisture-conservation methods of culture.
t C. Barley alternating with summer tillage.
t D. Summer tillage alternating with barley.

By "ordinary methods" is meant plowing to a depth of about 3 ches in the spring just before seeding, harrowing once, and seeding th a drill; no harrowing after seeding; no treatment of stubble d after harvest except to cut weeds to keep them from seeding.

By "conservation methods" is meant plowing to a depth of 8 ches immediately after harvest, thoroughly harrowing immediately ter plowing, keeping the soil in the best of tilth and free from weeds surface crust by frequent harrowings or diskings until seeding in e spring, thorough harrowing at time of seeding, and light harrow- gs at intervals to break crust and destroy weeds until the grain aches a height of about 6 inches. Under certain conditions, thor- gh disking immediately after harvest and deferring the plowing til the soil is in proper condition has been found to accomplish e desired results more effectually than immediate plowing, and in me cases this practice has been followed.

By "alternate summer tillage" is meant treating the soil after rvest as described under "conservation methods" until the fol- wing spring. Instead of then seeding it to crop, it is left bare or llow and is kept harrowed, disked, and free from weeds or surface rust until midsummer. It is then plowed again and treated the me as Group B thereafter, being seeded in like manner the following pring, Group D being summer tilled and Group C being cropped ne year and Group C being summer tilled and Group D being cropped ne next, and so on indefinitely, alternately cropping and summer illing.

The same variety and quantity of seed and the same drill are used pon all the plats of the same series for all groups at each station. t was found impracticable to use the same variety of each of the rains at all of the stations, as it has not been found possible to btain any one variety of any of these grains adapted to so wide a ange of soil and climatic conditions as is found between Montana n the north and Texas on the south. The rule has, therefore, been o select the variety of each of the grains best adapted to the locality. urum spring wheat has been used at all stations.

It was not practicable to use the same make of drill at all stations, nd there were other slight adaptations to local conditions, but the methods of seeding were essentially the same for the respectiv groups for all stations. The comparisons having been made betwee groups at each station instead of between stations, the slight differences mentioned could in no possible way affect the conclusions.

The accompanying tables give the yields in bushels per acre f each one of the 216 plats. They also give differences in bushels pe acre between the "A," or continuously cropped ordinary-metho plats, and "B," or continuously cropped moisture-conservation plat and the "C" or "D," alternately summer-tilled plats, respectivel The "A," or continuously cropped ordinary-method yields, are use as a basis for all comparison. The three tables represent, respectivel the three series—wheat, oats, and barley. The averages at the fo of each table are the average yields per acre in bushels and the ave age difference in bushels per acre between the groups for each serie respectively, for all of the 18 tests.

TABLE I.—*Comparison of yields to the acre of wheat series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or compared with Group
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bush*
Judith Basin, Mont	1909	33.0	33.4	34.0	+0.4	+
Dickinson, N. Dak	1908	24.3	17.7	33.8	−6.6	+
Do	1909	26.8	25.2	35.7	−1.6	+
Edgeley N. Dak	1907	4.1	7.0	9.9	+2.9	+
Do	1908	13.3	15.3	16.0	+2.0	+
Do	1909	28.3	23.3	27.0	−5.0	−
Highmore, S. Dak	1907	28.8	29.7	30.0	+ .9	+
Do	1908	26.3	19.7	30.7	−6.6	+
Bellefourche, S. Dak	1909	23.8	23.3	32.2	− .5	+
North Platte, Nebr	1907	24.5	26.0	31.8	+1.5	+
Do	1908	22.7	27.3	40.5	+4.6	+
Do	1909	23.0	15.3	18.0	−7.7	−
Akron, Colo	1909	14.3	10.3	18.5	−4.0	+
Hays, Kans	1908	1.2	4.5	4.2	+3.3	+
Garden City, Kans	1909	2.1	3.2	6.7	+1.1	+
Dalhart, Tex	1909	.0	.0	10.5	.0	+
Amarillo, Tex	1908	17.0	14.0	16.0	−3.0	−
Do	1909	.0	2.8	10.5	+2.8	+
Average		17.49	16.53	22.55	−0.86	+

TABLE II.—*Comparison of yields to the acre of oats series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or D compared with Group A.
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Basin, Mont	1909	75.3	66.2	78.7	− 9.1	+ 3.4
son, N. Dak	1908	48.4	32.8	61.9	−15.6	+13.5
o	1909	55.9	58.4	66.6	+ 2.5	+10.7
ey, N. Dak	1907	21.3	21.4	36.7	+ .1	+15.4
o	1908	16.9	15.3	....	− 1.6	....
o	1909	57.5	46.8	55.6	−10.7	− 1.9
nore, S. Dak	1907	45.3	47.2	59.4	+ 1.9	+14.1
o	1908	34.4	32.2	48.4	− 2.2	+14.0
ourche, S. Dak	1909	48.8	46.9	76.7	− 1.9	+27.9
Platte, Nebr	1907	30.0	36.0	30.0	+ 6.0	.0
o	1908	34.4	68.5	82.3	+34.1	+47.9
o	1909	31.3	24.1	46.3	− 7.2	+15.0
, Colo	1909	21.1	14.1	27.7	− 7.0	+ 6.6
, Kans	1908	1.3	3.7	3.5	+ 2.4	+ 2.2
n City, Kans	1909	1.0	3.2	7.9	+ 2.2	+ 6.9
rt, Tex	1909	.0	.0	13.4	.0	+13.4
illo, Tex	1908	20.0	32.2	31.6	+12.2	+11.6
o	1909	.0	.0	23.1	.0	+23.1
Average	....	30.16	30.5	44.11	+ 0.34	+13.18

TABLE III.—*Comparison of yields to the acre of barley series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or D compared with Group A.
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
th Basin, Mont	1909	45.2	43.3	49.4	− 1.9	+ 4.2
kinson, N. Dak	1908	33.5	23.9	30.0	− 9.6	− 3.5
Do	1909	39.8	39.0	50.0	− .8	+10.2
sley, N. Dak	1907	10.2	9.4	16.0	− .8	+ 5.8
Do	1908	25.0	24.2	24.2	− .8	− .8
Do	1909	27.0	24.7	28.3	− 2.3	+ 1.3
hmore, S. Dak	1907	30.2	37.1	40.2	+ 6.9	+10.0
Do	1908	29.8	26.0	46.7	− 3.8	+16.9
efourche, S. Dak	1909	23.8	25.0	37.3	+ 1.2	+13.5
th Platte, Nebr	1907	39.0	40.0	39.0	+ 1.0	.0
Do	1908	19.6	43.3	67.7	+23.7	+48.1
on, Colo	1909	19.7	16.8	24.6	− 2.9	+ 4.9
s, Kans	1908	5.8	12.4	18.9	+ 6.6	+13.1
den City, Kans	1909	2.4	4.8	10.0	+ 2.4	+ 7.6
hart, Tex	1909	.0	.0	7.5	.0	+ 7.5
arillo, Tex	1908	7.9	13.2	15.2	+ 5.3	+ 7.3
Do	1909	.0	5.8	17.5	+ 5.8	+17.5
Average	....	21.11	22.88	30.74	+ 1.76	+ 9.62

The most significant facts brought out by an inspection of t figures presented in Tables I, II, and III are as follows:

(1) The yields in thirteen out of the eighteen seasons cited are abo the normal for even the humid portions of the States where th stations are located, in some cases being more than double t normal.

(2) There are surprisingly small differences between the yiel obtained from the three different methods used, these differen being in many instances in the opposite direction from what mig be reasonably expected from the popular belief in the efficacy the methods followed.

(3) There is but a single instance where summer tillage and alt nate cropping increased the yields above the ordinary methods s ficiently to pay fully for the extra labor and expense involved. Th was at North Platte in 1908. The average results of the three yea tests at this station do not, however, show profitable returns for su mer tillage as compared with continuous cropping. The avera results of crop rotation have been more profitable than either co tinuous cropping or alternate cropping and summer tillage. (S Tables XXII and XXIII.)

(4) In all five instances (Edgeley, 1907; Hays, 1908; Garden Ci 1909; Dalhart, 1909; and Amarillo, 1909), where severe droug were experienced, the yields for the summer-tilled plats as compa with the ordinary-method plats were much greater, the ratios bei as follows: Edgeley—wheat 2.4 times, oats 1.7 times, barley 1 times; Hays—wheat 3.5 times, oats 2.7 times, barley 3.3 tim Garden City—wheat 3.2 times, oats 4.1 times, barley 7.9 tim At both Dalhart and Amarillo, in 1909, the ordinary-method pla were complete failures from drought, while the yields on the summe tilled plats were as follows: Dalhart—wheat 10.5 bushels, oats 13 bushels, barley 7.5 bushels per acre; Amarillo—wheat 10.5 bushe oats 23.1 bushels, barley 17.5 bushels per acre. None of these yiel obtained during these dry years were sufficient to make the cro profitable.

After a careful consideration of all the data submitted and all th arguments for and against the sufficiency of these data as a sa basis for conclusions, the following tentative conclusions are su mitted:

CONCLUSIONS CONCERNING SUMMER TILLAGE AND CONTINUOUS CROPPING.

(1) The practice of summer tillage and alternate cropping ca not be considered a safe basis for a permanent agriculture in th Great Plains area, where spring-sown wheat, oats, or barley are th staple crops.

) Summer tillage will almost invariably increase the yield of at, oats, or barley and will materially reduce the danger of com- s crop failure due to drought. It may therefore be resorted to safeguard or temporary expedient to meet a possible emergency, it can not be depended upon to produce as profitable spring- n crops as may be produced by other methods. Very good crops usually be raised by one plowing and one or two harrowings, as hown by yields obtained from continuous cropping by ordinary hods. Alternate cropping and summer tillage by methods used hese tests require on an average two plowings, four diskings, and ve harrowings. Each farmer must decide for himself whether an afford to perform this additional amount of labor in order to re an increase in yield, which if the season proves favorable may mall, and to materially reduce the danger of total failure if the on proves unfavorable. He should, however, remember that mer tillage will in no way reduce the many dangers other than ght, such as unseasonable frosts and high winds, to which crops subject. In fact, these dangers may be materially increased er a system of summer tillage.

t frequently happens that specially favorable soil conditions y in the spring induce such a rank growth of the young grain nts that the injury from both late spring frosts and summer ught is greatly increased. These factors were of such importance o completely reverse the results at North Platte, Nebr., in 1909. s moisture-conservation plats of wheat on both continuous crop- g and alternate cropping gave lower yields than the ordinary- thod plats, the loss due to good tillage being 7.7 bushels per acre continuous cropping and 5 bushels per acre for alternate cropping. eral other instances of the same nature are shown in Tables I, II, l III. This loss on well-tilled plats may in some instances be due proximate causes other than frost or drought. It seems reason- y certain, however, that the ultimate cause is usually over- nulation of the crop at some stage in its growth. It is a well- ognized fact among farmers that grain usually suffers more erely from rust when the growth is very rank and succulent than en it is less vigorous. A well-tilled soil may sometimes blow rse than a poorly tilled one.

(3) The result of the experiments with moisture-conservation thods upon continuously cropped plats are so contradictory that definite conclusions can be arrived at. This is true not only ere different stations are compared, but where the same station : different years, or the same stations for the same years with ferent crops, are compared. All the evidence, however, goes to ow that the time and depth of plowing and seeding and the har- wing of the grain after seeding are problems that are local in their

nature. The solutions of these problems are also so dependent up seasonal conditions of soil and climate that no safe generalizati concerning them can be made. Each farmer must therefore w out the best practice for his particular farm, crop, and season. is believed, however, that our investigations[a] show that fairly de plowing—about 8 inches—and thorough preparation of the seed b will give better results than shallower plowing on most soils, wheth spring or fall plowing is practiced. The deeper the plowing, th more thorough should be the harrowing in order to form a compa seed bed.

CROP ROTATION COMPARED WITH CONTINUOUS CROPPING.

OUTLINE OF THE THREE-YEAR ROTATIONS.

At the same eleven stations described in the previous pages, series of nine 3-year rotations were established at the same time th the continuous cropping experiments were begun. The plan of th rotations is described in the accompanying outline and in the expla atory notes following. These rotations are identical for all of th eleven stations.

Outline of 3-year rotations.

ROTATION No. 1.

Plat A. Spring wheat on corn ground disked but not plowed.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

ROTATION No. 2.

Plat A. Spring wheat on spring-plowed ground.
Plat B. Oats on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

ROTATION No. 3.

Plat A. Spring wheat on ground plowed early the preceding fall.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

ROTATION No. 4.

Plat A. Oats on corn ground not plowed but disked.
Plat B. Spring wheat on fall-plowed ground.
Plat C. Corn on fall-plowed ground.

ROTATION No. 5.

Plat A. Spring wheat on summer-tilled land.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Summer tilled.

ROTATION No. 6.

Plat A. Barley on corn ground not plowed but disked.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

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[a] See the discussion of crop rotation which follows.

ROTATION No. 7.

A. Oats on spring-plowed ground.
B. Barley on spring-plowed ground.
C. Corn on spring-plowed ground.

ROTATION No. 8.

A. Oats on summer-tilled land.
B. Spring wheat on ground plowed early the preceding fall.
C. Summer tilled.

ROTATION No. 9.

A. Oats on spring-plowed ground.
B. Spring wheat on spring-plowed ground.
C. Corn on spring-plowed ground.

The nine 3-year rotations are so planned as to give an oppor- nity to compare the several rotations considered as units and also compare the several crops grown in different rotations under stems of soil preparation and following different crops. As each tation is represented by three plats, each of the crops entering into e rotation is represented every year. This is a very important ature and one that has been neglected in most of the rotation periments heretofore made. By this system the differences in eld produced by the seasonal peculiarities are eliminated and it ay safely be assumed that any difference in yield that occurs in ny two crops of the same kind grown the same year in two rotations due either to the method of soil preparation or to crop sequence. Vhich of these two factors is the controlling one may usually be etermined by an easy method of cross-checking with the same rop in other rotations, whereby one or both factors may be elimi- iated.

As an example of some of the comparisons that may be made and he conclusions drawn, the following are suggested:

Rotations Nos. 1, 2, and 3 are identical so far as crops and sequence are concerned, but each differs from the other in soil preparation for the wheat crop. Any difference in the wheat yields in rotations Nos. 1 and 3 may safely be attributed to the effects of stubbling in No. 1 instead of fall plowing the corn ground as in No. 3, this being the only variable factor. The two rotations thus as units may be safely compared to determine the effect of stubbling upon the wheat crop and also upon the two crops which follow, namely, oats and corn. The oat crops in these rotations may be safely compared to see whether the effect of the soil preparation for the corn crop is apparent in the subsequent crop of oats. The corn crop in these two rotations being so far removed from the only variable factor should be about equal, and any difference will have to be accounted for in a way not apparent, except that in No. 2 spring plowing has been practiced, while Nos. 1 and 3 are fall plowed.

Rotations Nos. 2 and 3 are identical, except that spring plowing is practiced in No. 2, while No. 3 is fall plowed. This will give an opportunity to compare spring with fall plowing both upon the rotations as units and upon each of the several crops of the rotation.

Rotations Nos. 1 and 4 have the same crops in each, but their sequence is changed, oats instead of wheat being stubbled in after corn, with wheat following oats instead of oats following wheat. A comparison of these two wheat and oats crops will give some very definite information concerning the proper sequence of these two crops, as well as the proper relation of the corn crop to each. The relative effect of wheat and oats upon the following corn crop can also be studied.

Rotations Nos. 1, 2, and 3 may be compared with rotation No. 5 to ascertain the relative merits of summer-fallowing and cropping to corn as a preparation for a wheat crop, taking into consideration that but two crops are grown in three years in the case of No. 5, while three crops are grown in Nos. 1, 2, and 3.

In rotation No. 6 a barley crop has been substituted for the wheat crops which occur in all the preceding rotations. Many comparisons may be made between these six rotations that will throw much light upon sequence as well as cultivation.

Rotation No. 7 is like No. 6, except that the relative positions of oats and barley have been transposed. The same comparison may be made with this as with No. 6.

In rotation No. 8 we have another chance to compare summer fallow with corn as a preparation for small-grain crops, oats being the crop used to follow the summer fallow in this instance. A comparison of No. 8 with No. 4 will bring out the relative value of corn and summer fallow as a preparation for oats, and a comparison with No. 1 and No. 5 will show whether the best results will be obtained from using wheat, oats, or barley as a crop to follow corn or summer-fallow.

Rotation No. 9 is identical with No. 3, except that the sequence is changed.

Besides the comparisons already mentioned, the list of which might be indefinitely extended, each one of the nine rotations may be compared as a unit with any other.

We have seven crops of wheat growing each year, as follows:

No. 1. Wheat after corn—stubbled in.
No. 2. Wheat after corn—spring plowing.
No. 3. Wheat after corn—fall plowing.
No. 4. Wheat after oats—fall plowing.
No. 5. Wheat after summer fallow.
No. 8. Wheat after oats—fall plowing.
No. 9. Wheat after oats—spring plowing.

Ve have seven crops of corn, grown as follows:

1. Corn after oats—fall plowing.
2. Corn after oats—spring plowing.
3. Corn after oats—fall plowing.
4. Corn after wheat—fall plowing.

No. 6. Corn after oats—fall plowing.
No. 7. Corn after barley—spring plowing.
No. 9. Corn after wheat—spring plowing.

Oats enter into each of the nine rotations, and have been grown as lows:

. 1. Oats after wheat—fall plowing.
. 2. Oats after wheat—spring plowing.
. 3. Oats after wheat—fall plowing.
. 4. Oats after corn—stubbled in.
. 5. Oats after wheat—fall plowing.

No. 6. Oats after barley—fall plowing.
No. 7. Oats after corn—spring plowing.
No. 8. Oats after summer fallow.
No. 9. Oats after corn—spring plowing.

Barley enters into but two of the rotations, as follows:

. 6. Barley after corn—stubbled in.
No. 7. Barley after oats—spring plowing.

An inspection of this tabular arrangement of the crops will at once ow that there are a very large number of questions concerning soil eparation and crop sequence that may be definitely answered by is series of experiments, not from the result of a single instance but y a system of cross-checking from the results of several crops grown ery year under different systems of soil preparation and crop quence.

EXPLANATORY NOTES.

The purposes of this series of rotations are to test the effect of crop quence and time of plowing.

Good farming is practiced upon all the plats. No special methods f moisture conservation are contemplated in this experiment. Plowing is to a depth of 8 inches and is uniform for all plats.

Fall plowing is done as early in the season as practicable. Whether he land is disked or harrowed or left undisturbed after fall plowing s left to the judgment of the man immediately in charge. Whatever ractice in this respect is adopted for one of these rotations is followed or all in this series. The same general rule is applied to plowing nd the fitting of the seed bed in the spring. Such an amount of work s done upon the land as will put it in good tilth.

In spring plowing for corn the rule has been to have the plowing deferred until corn-planting time, and for the planter to follow as closely after the plowing as possible and the harrow immediately after the planter. In some instances it has seemed desirable to disk or harrow the ground before spring plowing for corn. This is left to the judgment of the man in charge.

The summer-tilled plats in this series have been treated like the summer-tilled plats in the moisture-conservation series discussed in the previous pages.

These rotations were not planned nor are they here presented as the best rotations for the Great Plains area. They are seriously defective in that they make no provision for maintaining or restoring the organic matter to the soil. They were established for the purpose of studying the effects of crop sequence, or the effect that one crop has upon the crops following it, and the relative merits of fall and spring plowing. For these purposes these simple rotations have some marked advantages over longer and better rotations. This phase of the experiments will be but very briefly mentioned at this time, although it is believed that the thoughtful reader may find some very interesting, although possibly not conclusive, evidence on these subjects by a careful study of these tables. This subject will be more fully treated in some future publication. The purpose of introducing these figures at this time is to show that even these defective 3-year rotations have given better net results than either the continuous cropping or alternate cropping and summer tillage described in the foregoing pages. By "better net results" is meant that at nearly all stations the yields have been better for all three crops—wheat, oats, and barley—where the rotation of crops has been practiced than where the same crop has been grown continuously on the same ground. This statement is equally true concerning both ordinary methods and moisture-conservation methods of continuous cropping. The labor and expense involved in raising crops under a system of rotation are not materially greater than where continuous cropping by ordinary methods is practiced. The labor and expense of raising crops under moisture-conservation methods of continuous cropping are materially greater than under a system of crop rotation, as these two systems have been practiced in these experiments.

Where but one crop is raised in two years, as in the case of alternate cropping and summer tillage, the labor and expense per crop are nearly or quite double that of either rotation or continuous cropping by ordinary methods. In order, then, to make the net results as favorable under alternate cropping as under either continuous cropping or crop rotation, the yields should be nearly double. Summer tillage has nearly always increased the yields, but it has seldom doubled them. In only a few instances has this increase been sufficient to pay the bare expenses of the additional labor involved. Crop rotation has therefore given better net returns than either alternate cropping and summer tillage or continuous cropping by either ordinary methods or moisture-conservation methods, as is shown by Tables XXII and XXIII.

A COMMON BASIS OF COMPARISON.

In order to answer many of the important questions concerning the relation and adaptability of rotations, it is apparent that we must have some common basis of comparison for the several crops wn in the rotation. The rotations giving the best yields of wheat dom give the best yields of oats, and the best rotations calculated an oat basis are not the best for barley. In order to make the cessary comparisons we must be able to reduce the figures representing the yields in bushels per acre of all the crops in the rotation a common unit of measurement. This has been done for wheat, rn, oats, and barley.

The Bureau of Statistics reports[a] as follows concerning the average farm price per bushel for the ten years 1900–1909, inclusive:

Average price per bushel for wheat, corn, oats, and barley, in four States, 1900–1909.

State.	Wheat.	Corn.	Oats.	Barley.
	Cents.	*Cents.*	*Cents.*	*Cents.*
orth Dakota	68	44	31	38
outh Dakota	67	37	29	37
ebraska	63	35	29	36
ansas	67	40	33	39
Average	66	39	30	38

These four States were selected as giving a more reliable basis than could be obtained by including Montana, Wyoming, Colorado, Oklahoma, Texas, and New Mexico. All of these latter-named States have a portion of their territory lying within territory where local conditions of supply and demand very seriously affect both the relative and the absolute prices. On the other hand, the four States first named lie entirely within the Plains region, with sufficiently free access to the large grain markets to insure them against any serious influence from purely local conditions. The figures given will therefore be used, after making one correction, for calculating the value of the rotations. This one correction is in the case of the price for wheat. The figures given are the averages for all the wheat marketed in the four States specified. This includes durum as well as common wheats. Durum wheats were used exclusively in our experiments with spring wheat. The price of durum wheat has nearly always been less than the averages for all wheats—just how much lower on the average for the last ten years we have no means of knowing. Neither have we any satisfactory basis for calculating the percentage of durum to the entire wheat crop of these States. It has therefore been decided to arbitrarily reduce the above estimate to 60 cents per bushel for durum wheats. It is probable that the reduction should be greater than this rather than less, but in the absence of any more satisfactory basis the following prices in cents per bushel have been adopted:

Durum wheat	60	Oats	30
Corn	39	Barley	38

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[a] Crop Reporter, December, 1909, p. 82.

While these values per bushel seem to be the most reliable obtainable, they are open to several objections, among which are the following:

They are much too low for all crops to agree with present prices, or those obtaining when these investigations were made. As it is the relative rather than the absolute prices of these crops that are of most importance, this defect is not so serious as some others. If these prices were relatively correct, they could be raised horizontally to suit market prices at any given time, without disturbing their relations to each other, by simply multiplying them by some factor which would bring them all up to the proper figure. A much more serious defect is found in the fact that the average prices for the last ten years do not bear the same relation to each other that the crop-producing power of the soil bears to those prices when sown to these crops under exactly the same conditions. To illustrate, we give below the average yields obtained from each of the three grain crops in all the 18 tests under continuous cropping by ordinary methods and by crop rotation, with the value per acre, calculated on the basis of the farm price per bushel for the last ten years:

TABLE IV.—*Average yields on experimental plats, in bushels, and average farm value per acre, based on the average prices for ten years, 1900–1909, inclusive, in North and South Dakota, Nebraska, and Kansas.*

Cropping method.	Wheat.	Oats.	Barley.	Price per bushel.	Farm value per acre.
	Bushels.	*Bushels.*	*Bushels.*	*Cents.*	
Continuous cropping, ordinary methods	17.4			60	$10.44
Do		30.2		30	9.06
Do			21.1	38	8.02
Three-year rotation	19.8			60	11.88
Do		36.3		30	10.89
Do			24.3	38	9.23

It will be seen that wheat under continuous cropping produced a farm value per acre of $10.44, while oats produced only $9.06 and barley $8.02. The land upon which these yields were obtained was the same for each of the three crops. The climatic conditions and the preparation of the soil were the same. The cost of raising the crop was essentially the same for all the crops. Therefore, the farm value per acre should have been the same if the farmer were to receive the same profit on each crop. Such, however, was not the case, as shown by the above figures. In order to make the same profit from all the crops, it would have been necessary to secure 34½ cents per bushel for oats, instead of 30 cents and 49½ cents per bushel for barley. With crop rotation the results are similar; the price for oats should have been 33 cents and for barley 49 cents to make the farm value per acre the same as for wheat at 60 cents per ushel. Figuring wheat on a 90-cents-per-bushel basis, which is pproximately the present market price, oats should bring about 1 cents and barley about 73 cents per bushel. This is considerably n excess of present farm prices for oats and barley, which shows hat they are at present and have been for the last ten years relaively too low in comparison with wheat.

This is an important consideration with every farmer who is planning to diversify his crops in order to adopt a system of crop rotation. It is evident that in order to receive equal immediate cash returns for his crops he must accomplish one or more of the following results:

(1) He must, by selecting varieties especially adapted to the locality or by better methods of tillage, increase the relative yields of oats and barley as compared with wheat above those obtained in these investigations; or (2) he must, by raising oats or barley of superior quality, obtain prices in advance of the average market price; or (3) he must, by feeding these grains, realize more than the market price for them; or (4) he must, by adopting a rotation of crops instead of cropping continuously to the same crop, improve the condition of his farm, and by reducing the loss from weeds, diseases, and insect attacks increase the yields of all the crops grown so as to make the net returns from his farm equal to or greater than those obtainable from continuous cropping to wheat.

It is probable that most of the results mentioned may be obtained by adopting a proper system of crop rotation. The value of the results so obtained and the best method of obtaining them depend largely upon local conditions of soil and climate, the market prices for grain and live stock, and frequently upon various other conditions more or less local or individual in their nature. Such being the case, each farmer must necessarily depend largely upon his own judgment and knowledge of these conditions in deciding how best to accomplish the desired results.

The discussion of the results of these investigations will, therefore, be confined mainly to showing what may reasonably be expected from increased yields due directly to crop rotation as compared with continuous cropping.

Table V has been prepared by using the same values per bushel as in Table IV and the yields from continuous cropping by ordinary methods at each of the stations as a basis. The figures given in the table in the column headed "Average for wheat and oats" have been used as a basis of comparison with rotations 1, 2, 3, 4, 5, 8, and 9 in Tables XXII and XXIII. The figures in column headed "Average for barley and oats" have been used as a basis of comparison with rotations 6 and 7 in the same tables. The figures given in the columns headed "Wheat at 60 cents," "Oats at 30 cents," and "Barley at 38 cents," respectively, may be used to make comparisons of yields per acre and farm values per acre between continuous cropping and crop rotation for wheat, oats, or barley in any rotation or for any test reported in Tables VI to XIV, inclusive.

TABLE V.—*Yields from continuous cropping by ordinary methods, in bushels and in farm value per acre, at average prices for the ten years 1900–1909, inclusive.*

Station.	Year.	Wheat at 60 cents.		Oats at 30 cents.		Barley at 38 cents.		Average for wheat and oats.	Average for barley and oats.
		Bush.		*Bush.*		*Bush.*			
Judith Basin, Mont.	1909	33.0	$19.80	75.3	$22.59	45.2	$17.20	$21.20	$19.90
Dickinson, N. Dak.	1908	24.3	14.58	48.4	14.52	33.5	12.73	14.55	13.62
Do.	1909	26.8	16.08	55.9	16.77	39.8	15.12	16.42	15.95
Edgeley, N. Dak.	1907	4.1	2.46	21.3	6.39	10.2	3.88	4.43	5.13
Do.	1908	13.3	7.98	16.9	5.07	25.0	9.50	6.53	7.28
Do.	1909	28.3	16.98	57.5	17.25	27.0	10.26	17.11	13.75
Highmore, S. Dak.	1907	28.8	17.28	45.3	13.59	30.2	11.48	15.44	12.53
Do.	1908	26.3	15.78	34.4	10.32	29.8	11.32	13.05	10.82
Bellefourche, S. Dak.	1909	23.8	14.28	48.8	14.64	23.8	9.04	14.46	11.84
North Platte, Nebr.	1907	24.5	14.70	30.0	9.00	39.0	14.82	11.85	11.91
Do.	1908	22.7	13.62	34.2	10.34	19.6	7.45	11.98	8.90
Do.	1909	23.0	13.80	31.3	9.39	....	....	11.59	9.39
Akron, Colo.	1909	14.3	8.58	21.1	6.33	19.7	7.49	7.46	6.91
Hays, Kans.	1908	1.2	.72	1.3	.39	5.8	2.20	.56	1.30
Garden City, Kans.	1909	2.1	1.26	1.0	.30	2.4	.91	.78	.61
Dalhart, Tex.	1909	0.0	0.00	0.0	0.00	0.0	0.00	0.00	0.00
Amarillo, Tex.	1908	17.0	10.20	20.0	6.00	7.9	3.00	8.10	4.50
Do.	1909	0.0	0.00	0.0	0.00	0.0	0.00	0.00	0.00
Average	....	17.4	10.44	30.2	9.06	21.1	8.02	9.75	8.53

The following nine tables, Tables VI to XIV, inclusive, show in detail the yields per acre in bushels and the farm value per acre for each of the three crops grown in the nineteen tests. The farm values have been calculated on the basis of 60 cents for wheat, 30 cents for oats, 38 cents for barley, and 39 cents for corn.

In these tables the average farm values in dollars per acre of the two small-grain crops only in each rotation have been considered. Seven of these rotations contain corn crops, and two of them, Nos. 5 and 8, a year of summer tillage each. There is therefore one factor—the yield of the corn crop—which has so far been neglected in considering the relative yields of the rotations. This omission is to be regretted, but it seemed unavoidable for the following reasons:

(1) The corn crop lends itself much less readily to growing on small plats so as to give results comparable to those of large fields than do wheat, oats, and barley. While careful records of all corn yields have been kept, they are not entitled to the same confidence as the small-grain yields. (2) Very little, if any, of the Great Plains area can be considered as a corn-growing country. In most of the area corn can and will be profitably grown, but a considerable share of the profit from its growth will be derived from the beneficial effect

ich the growing of the corn crop has in preparing the soil for the ps of small grain which are to follow it in rotation.

It is assumed that the corn crop will produce enough in the form fodder and grain to at least pay for the labor involved in its pro-ction. The labor involved in raising a crop of corn is no greater an that required to summer till an equal area. In comparing the elds obtained from the small-grain crops in a rotation containing mmer tillage with one containing corn it has been assumed that the elds from the summer-tillage rotation must be enough in excess of ose from the corn rotation to pay for the summer tillage. Or, to t it in another way, the corn crop must be sufficient to equal in lue the excess in yield of the two small-grain crops in the summer-lled over those in the corn rotation. Whatever form of compari-n is used it is assumed that the labor required to produce a crop of rn is approximately the same as to summer till. The corn crop ays for the work bestowed upon it, while the summer-tilled rotation ust produce enough more small grain to pay for the cost of the sum-er tillage.

Corn should therefore be much more commonly grown than it now in this area, not because it is a profitable crop in itself, but because takes the place of summer tillage in the rotation and at least pays r the labor bestowed upon it. A corn crop might therefore be con-idered a complete failure judged from the standpoint of grain pro-uction, but still yield enough in the way of rough fodder and be valu-ble enough in its effect upon subsequent crops in the rotation to make t a very profitable crop.

In the double columns headed "Corn" are given the yields in ushels per acre and the farm value per acre based upon the actual ields of grain wherever the crop matured. The yields of fodder are lso given in pounds per acre, but no value is calculated for this por-ion of the crop. It will be noticed that in many instances a good ield of fodder was obtained without any reported yield of grain. This is due to the failure of the crop to mature. The selection of an earlier maturing variety would undoubtedly in many instances have resulted in a good yield of grain. The corn yields do not enter into the valuation of the rotation. These figures are given simply to show that corn can be grown at these stations.

Table VI.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

Rotation No. 1.

Plat A. Spring wheat on corn ground disked but not plowed.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	34.8	$20.88	68.1	$20.43	......	......	8.160	[illegible]
Dickinson, N. Dak.	1908	35.8	21.48	35.3	10.59	......	......	2.050	[illegible]
Do.	1909	39.8	23.88	64.4	19.32	50.7	$19.77	2.080	[illegible]
Edgeley, N. Dak.	1907	16.7	10.02	25.9	7.77	......	......	4.150	[illegible]
Do.	1908	24.0	14.40	26.3	7.89	......	......	2.600	[illegible]
Do.	1909	33.0	19.80	64.0	19.20	30.8	12.01	3.150	[illegible]
Highmore, S. Dak.	1906	26.7	16.02	45.3	13.59	33.1	12.91	......	[illegible]
Do.	1907	21.5	12.90	46.9	14.07	21.4	8.35	......	[illegible]
Do.	1908	24.3	14.58	28.8	8.64	16.4	6.40	......	[illegible]
Bellefourche, S. Dak.	1909	29.4	17.64	55.6	16.68	20.7	8.07	3,370	[illegible]
North Platte, Nebr.	1907	22.3	13.38	26.9	8.07	14.4	5.62	5,080	[illegible]
Do.	1908	28.6	17.16	60.3	18.09	31.8	12.40	3,620	[illegible]
Do.	1909	21.7	13.02	23.1	6.93	25.1	9.79	2,490	[illegible]
Akron, Colo.	1909	25.0	15.00	25.6	7.68	26.4	10.30	1,909	[illegible]
Hays, Kans.	1908	3.7	2.22	28.5	8.55	4.2	1.64	6,665	[illegible]
Garden City, Kans.	1909	1.0	.60	3.0	.90	......	.00	2,820	[illegible]
Dalhart, Tex.	1909	.0	.00	.0	.00	......	.00	650	[illegible]
Amarillo, Tex.	1908	8.3	4.98	28.1	8.43	16.6	6.48	2.740	[illegible]
Do.	1909	.0	.00	10.0	3.00	......	.00	1.610	[illegible]
Average.	......	20.87	12.52	35.06	10.52	......	......	......	[illegible]

Table VII.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

Rotation No. 2.

Plat A. Spring wheat on spring-plowed ground.
Plat B. Oats on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	33.1	$19.86	63.1	$18.93	......	......	6,650	[illegible]
Dickinson, N. Dak.	1908	35.0	21.00	52.5	15.75	......	......	1,340	[illegible]
Do.	1909	39.7	23.82	60.6	18.18	49.7	$19.38	2,180	[illegible]
Edgeley, N. Dak.	1907	13.2	7.92	29.7	8.91	......	......	3,150	[illegible]
Do.	1908	15.8	9.48	20.6	6.18	......	......	2,500	[illegible]
Do.	1909	32.6	19.56	63.7	19.11	31.3	12.21	3,350	[illegible]
Highmore, S. Dak.	1906	27.3	16.38	38.8	11.64	42.7	16.55	......	[illegible]
Do.	1907	29.0	17.40	41.6	12.48	21.4	8.35	......	[illegible]
Do.	1908	25.2	15.12	36.9	11.07	28.8	11.23	......	[illegible]
Bellefourche, S. Dak.	1909	23.9	14.34	42.5	12.75	17.2	6.71	3,180	[illegible]
North Platte, Nebr.	1907	23.7	14.22	32.3	9.69	17.0	6.63	4,430	[illegible]
Do.	1908	24.0	14.40	36.9	11.07	31.6	12.32	3,110	12.73
Do.	1909	17.2	10.32	28.1	8.43	25.0	9.75	1,900	9.37
Akron, Colo.	1909	20.8	12.48	18.3	5.49	26.3	10.26	2,760	[illegible]
Hays, Kans.	1908	1.5	.90	26.0	7.80	16.0	6.24	4,380	[illegible]
Garden City, Kans.	1909	4.0	2.40	1.3	.39	......	......	2,260	[illegible]
Dalhart, Tex.	1909	.0	.00	.0	.00	......	......	850	.00
Amarillo, Tex.	1908	8.0	4.80	2.34	7.02	12.9	5.03	2,950	5.91
Do.	1909	.0	.00	.0	.00	......	......	1,500	.00
Average.	......	19.68	11.81	32.44	9.73	16.84	......	......	10.77

E VIII.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 3.

lat A. Spring wheat on ground plowed early the preceding fall.
lat B. Oats on ground plowed early the preceding fall.
lat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
h Basin, Mont	1909	31.0	$18.60	61.5	$18.45	....	....	8,960	$18.53
inson, N. Dak	1908	35.0	21.00	38.9	11.67	....	....	2,510	16.33
Do	1909	37.3	22.38	62.5	18.75	48.3	$18.84	1,940	20.57
ley, N. Dak	1907	12.6	7.56	30.5	9.15	....	....	3,150	8.35
Do	1908	20.8	12.48	16.9	5.07	....	....	1,900	8.78
Do	1909	32.5	19.50	66.5	19.95	29.0	11.31	2,750	19.72
more, S. Dak	1906	25.5	15.30	47.2	14.16	39.1	15.25	....	14.73
Do	1907	27.2	16.32	45.3	13.59	22.9	8.93	....	14.96
Do	1908	25.7	15.42	29.7	8.91	19.6	7.64	....	12.16
fourche, S. Dak	1909	29.9	17.94	53.6	16.08	17.8	6.94	3,415	17.01
h Platte, Nebr	1907	20.7	12.42	30.6	9.18	19.6	7.64	4,670	10.80
Do	1908	27.7	16.62	60.3	18.09	33.7	13.14	3,430	17.36
Do	1909	24.3	14.58	18.3	5.49	22.6	8.71	2,170	10.04
n, Colo	1909	19.2	11.52	18.8	5.64	25.7	10.02	4,400	8.58
s, Kans	1908	3.9	2.34	20.1	6.03	5.7	2.22	5,700	4.19
len City, Kans	1909	2.2	1.32	.0	.00	....	.00	2,940	.66
art, Tex	1909	.0	.00	.0	.00	....	.00	1,000	.00
rillo, Tex	1908	8.5	5.10	27.5	8.25	17.6	6.86	3,250	6.67
Do	1909	.0	.00	17.8	5.34	....	.00	1,430	2.67
Average	....	20.21	12.30	34.0	10.20	....	....	....	11.16

BLE IX.—*Yields of oats, wheat, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 4.

Plat A. Oats on corn ground, not plowed but disked.
Plat B. Spring wheat on fall-plowed ground.
Plat C. Corn on fall-plowed ground.

Station.	Year.	Oats.		Wheat.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
dith Basin, Mont	1909	74.1	$22.23	33.3	$19.98	....	....	7,040	$21.11
ckinson, N. Dak	1908	67.2	20.16	18.8	11.28	....	....	2,330	15.72
Do	1909	72.5	21.75	34.3	20.58	48.9	$19.07	2,000	21.17
igeley, N. Dak	1907	28.8	8.64	10.5	6.30	....	....	2,850	7.47
Do	1908	23.4	7.02	15.7	9.42	....	....	1,750	8.22
Do	1909	63.7	19.11	28.5	17.10	32.1	12.52	2,950	18.10
ighmore, S. Dak	1906	61.6	18.48	25.0	15.00	36.1	14.08	....	16.74
Do	1907	48.4	14.52	29.0	17.40	22.6	8.81	....	15.96
Do	1908	35.6	10.68	21.8	13.08	8.4	3.27	....	11.88
ellefourche, S. Dak	1909	75.0	22.50	29.7	17.82	19.8	7.72	3,215	20.16
orth Platte, Nebr	1907	40.6	12.18	24.2	14.52	17.7	6.90	4,570	13.35
Do	1908	54.3	16.29	31.3	18.78	30.0	11.70	3,670	17.54
Do	1909	22.5	6.75	16.8	10.08	29.6	11.54	2,730	8.41
kron, Colo	1909	21.3	6.39	10.6	6.36	23.1	9.01	2,340	6.38
ays, Kans	1908	16.0	4.80	6.7	4.02	5.4	2.11	5,160	4.41
arden City, Kans	1909	2.9	.87	.9	.54	....	....	2,440	.70
alhart, Tex	1909	.0	.00	.0	.00	....	....	850	.00
marillo, Tex	1908	22.8	6.84	13.2	7.92	17.6	6.86	3,280	7.38
Do	1909	.0	.00	.0	.00	....	....	1,510	.00
Average	....	38.46	11.54	18.44	11.06	....	....	....	11.30

TABLE X.—*Yields of wheat and oats in bushels per acre and farm value per acre in [illegible]teen tests, 1906-1909, inclusive.*

ROTATION NO. 5.

Plat A. Spring wheat on fallow land.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Summer tillage.

Station.	Year.	Wheat.		Oats.		Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		
Judith Basin, Mont	1909	38.0	$22.80	67.1	$20.13	[illegible]
Dickinson, N. Dak	1908	33.0	19.80	39.4	11.82	[illegible]
Do	1909	37.7	22.62	63.8	19.14	[illegible]
Edgeley, N. Dak	1907	11.8	7.08	27.5	8.25	[illegible]
Do	1908	19.5	11.70	33.4	10.02	[illegible]
Do	1909	29.8	17.88	63.7	19.11	[illegible]
Highmore, S. Dak	1906	31.7	19.02	46.6	13.98	[illegible]
Do	1907	33.3	19.98	55.0	16.50	[illegible]
Do	1908	29.0	17.40	27.8	8.34	[illegible]
Bellefourche, S. Dak	1909	31.4	18.84	51.6	15.48	[illegible]
North Platte, Nebr	1907	26.0	15.60	31.2	9.36	[illegible]
Do	1908	42.2	25.32	54.7	16.41	[illegible]
Do	1909	27.2	16.32	19.1	5.73	[illegible]
Akron, Colo	1909	18.2	10.92	16.7	5.01	[illegible]
Hays, Kans	1908	4.1	2.46	22.8	6.84	[illegible]
Garden City, Kans	1909	6.6	3.96	3.3	.99	[illegible]
Dalhart, Tex	1909	7.7	4.62	.0	.00	[illegible]
Amarillo, Tex	1908	16.5	9.90	24.4	7.32	[illegible]
Do	1909	9.5	5.70	15.3	4.59	[illegible]
Average	....	28.35	14.31	34.92	10.47	[illegible]

TABLE XI.—*Yields of barley, oats, and corn in bushels per acre and farm value per ac in nineteen tests, 1906-1909, inclusive.*

ROTATION NO. 6.

Plat A. Barley on corn ground, not plowed but disked.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Barley.		Oats.		Corn.		Corn fodder.	Average value per acre of barley and oats.
		Bushels		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont	1909	42.7	$16.23	57.8	$17.34	....	....	8,320	$16.79
Dickinson, N. Dak	1908	45.6	17.33	44.7	13.41	....	....	2,100	15.37
Do	1909	53.8	20.44	61.9	18.57	50.3	$19.62	2,000	19.50
Edgeley, N. Dak	1907	18.3	6.95	32.5	9.75	....	....	2,650	8.35
Do	1908	31.9	12.12	15.9	4.77	....	....	2,350	8.45
Do	1909	33.1	12.58	60.3	18.09	29.8	11.62	2,400	15.33
Highmore, S. Dak	1906	37.7	14.33	53.8	16.14	36.1	14.08	....	15.24
Do	1907	25.0	9.50	49.4	14.82	20.0	7.80	....	12.16
Do	1908	30.0	11.40	36.3	10.89	18.4	7.18	....	11.14
Bellefourche, S. Dak	1909	47.1	17.90	65.6	19.68	19.2	7.49	3,460	18.79
North Platte, Nebr	1907	30.6	11.63	23.1	6.93	20.0	7.80	4,410	9.28
Do	1908	24.9	9.46	49.1	14.73	23.2	9.05	2,870	12.09
Do	1909	21.5	8.17	19.7	5.91	31.7	12.36	2,090	7.04
Akron, Colo	1909	24.9	9.46	20.8	6.24	26.1	10.18	2,720	7.85
Hays, Kans	1908	12.3	4.67	35.5	10.65	5.5	21.45	6,115	7.66
Garden City, Kans	1909	5.1	1.94	3.1	.93	....	....	2,500	1.44
Dalhart, Tex	1909	.0	.00	.0	.00	....	....	650	.00
Amarillo, Tex	1908	7.5	2.85	31.3	9.39	18.3	7.14	3,200	6.12
Do	1909	.0	.00	.0	.00	....	....	1,220	.00
Average	....	25.9	9.84	34.78	10.43	....	....	....	10.14

B XII.—*Yields of oats, barley, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION No. 7.

at A. Oats on spring-plowed ground.
at B. Barley on spring-plowed ground.
at C. Corn on spring-plowed ground.

Station.	Year.	Oats.		Barley.		Corn.		Corn fodder.	Average value per acre of oats and barley.
		Bushels		*Bushels*		*Bushels.*		*Pounds.*	
h Basin, Mont	1909	74.0	$22.20	39.1	$14.86	....	....	7,120	$18.53
nson, N. Dak	1908	60.9	18.27	34.4	13.07	....	....	1,480	15.67
o	1909	70.3	21.09	49.2	18.70	46.7	$18.21	2,000	19.89
ley, N. Dak	1907	24.8	7.44	10.6	4.03	....	....	1,950	5.74
o	1908	24.7	7.41	26.0	9.88	....	....	2,550	8.65
o	1909	60.9	18.27	32.7	12.43	29.8	11.62	2,800	15.35
more, S. Dak	1906	57.5	17.25	29.2	11.10	43.1	16.81	....	14.17
o	1907	43.8	13.14	28.3	10.75	28.6	11.15	....	11.95
Do	1908	40.0	12.00	29.9	11.36	32.6	12.71	....	11.68
fourche, S. Dak	1909	58.8	17.64	28.1	10.68	20.6	8.03	2,980	14.16
h Platte, Nebr	1907	35.7	10.71	40.2	15.28	22.6	8.81	4,690	12.99
Do	1908	60.3	18.09	22.3	8.47	31.7	12.36	3,630	13.28
Do	1909	35.0	10.50	18.5	7.03	22.1	8.62	2,950	8.77
on, Colo	1909	25.6	7.68	22.2	8.44	21.7	8.46	2,380	8.06
len City, Kans	1909	3.8	1.14	5.7	2.17	....	....	2,660	1.65
, Kans	1908	15.2	4.56	9.2	3.50	4.0	1.56	4,540	4.08
hart, Tex	1909	.0	.00	.0	.00	....	....	900	.00
rillo, Tex	1908	21.3	6.39	8.1	3.08	17.0	6.63	2,950	4.73
Do	1909	.0	.00	.0	.00	....	....	1,380	.00
Average	....	37.5	11.26	22.83	8.67	16.87	6.58	....	9.97

BLE XIII.—*Yields of oats and wheat in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION No. 8.

Plat A. Oats on fallow land.
Plat B. Spring wheat on ground plowed early the preceding fall.
Plat C. Summer tillage.

Station.	Year.	Oats.		Wheat.		Average value per acre of oats and wheat.
		Bushels.		*Bushels.*		
dith Basin, Mont	1909	66.2	$19.96	40.3	$24.18	$22.02
ickinson, N. Dak	1908	60.9	18.27	20.5	12.30	15.29
Do	1909	74.7	22.41	35.0	21.00	21.70
dgeley, N. Dak	1907	30.9	9.27	8.5	5.10	7.19
Do	1908	20.9	6.27	10.3	6.18	6.22
Do	1909	56.2	16.86	26.6	15.96	16.41
ighmore, S. Dak	1906	83.4	25.02	25.0	15.00	20.01
Do	1907	57.8	17.34	32.7	19.62	18.48
Do	1908	46.6	13.98	27.5	16.50	15.24
ellefourche, S. Dak	1909	85.2	25.56	33.2	19.92	22.74
orth Platte, Nebr	1907	40.9	12.27	28.3	16.98	14.63
Do	1908	91.5	27.45	31.3	18.78	23.11
Do	1909	.00	.00	16.8	10.08	5.04
Akron, Colo	1909	28.3	8.49	10.9	6.54	7.52
Hays, Kans	1908	28.8	8.64	4.2	2.52	5.58
Garden City, Kans	1909	5.8	1.74	3.8	2.28	2.01
Dalhart, Tex	1909	10.0	3.00	.0	.00	1.50
Amarillo, Tex	1908	33.4	10.00	13.7	8.22	9.12
Do	1909	25.6	7.68	.0	.00	3.84
Average	....	44.56	13.37	19.4	11.64	12.51

TABLE XIV.—*Yields of oats, wheat, and corn in bushels per acre and farm value per in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 9.

Plat A. Oats on spring-plowed ground.
Plat B. Spring wheat on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

Station.	Year.	Oats.		Wheat.		Corn.		Corn fodder.	[illegible]
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont	1909	70.7	$21.21	31.6	$18.96			7,280	[illegible]
Dickinson, N. Dak	1908	50.6	15.18	18.7	11.22			2,800	[illegible]
Do	1909	71.3	21.39	30.7	18.42	43.5	$16.97	1,680	[illegible]
Edgeley, N. Dak	1907	5.6	1.68	4.2	2.52			2,300	[illegible]
Do	1908	16.9	5.07	13.5	8.10			2,680	[illegible]
Do	1909	58.7	17.61	25.8	15.48	29.3	11.43	3,050	[illegible]
Highmore, S. Dak	1906	56.9	17.07	25.7	15.42	38.1	14.86		[illegible]
Do	1907	47.5	14.25	24.5	14.70	27.1	10.57		[illegible]
Do	1908	41.6	12.48	24.2	14.52	25.9	10.10		[illegible]
Bellefourche, S. Dak	1909	62.2	18.66	26.1	15.66	22.7	8.85	4,905	[illegible]
North Platte, Nebr	1907	33.4	10.02	20.8	12.48	18.6	7.25	4,830	[illegible]
Do	1908	48.2	14.46	17.5	10.50	28.0	10.92	3,490	[illegible]
Do	1909	27.5	8.25	16.7	10.00	27.1	10.57	3,330	[illegible]
Akron, Colo	1909	17.5	5.25	14.3	8.58	25.3	9.87	2,280	[illegible]
Hays, Kans	1908	19.1	5.73	2.2	1.32	4.3	1.68	4,130	[illegible]
Garden City, Kans	1909	2.3	.69	2.5	1.50		.00	2,900	[illegible]
Dalhart, Tex	1909	.0	.00	.0	.00		.00	1,200	[illegible]
Amarillo, Tex	1909	22.5	6.75	5.3	3.18	14.3	5.58	2,680	[illegible]
Do	1909	.0	.00	.0	.00		.00	1,270	[illegible]
Average		34.34	10.30	16.03	9.61				[illegible]

Tables XV, XVII, and XIX present in convenient form for comparison the yields per acre of each rotation for each test and each crop, the average yields for continuous cropping, and the losses or gains as compared with crop rotations for each test.

In Tables XVI, XVIII, and XX the yields are expressed in farm values per acre instead of in bushels, Tables XV and XVI, XVII and XVIII, XIX and XX being, respectively, companion tables dealing with the same crops, but using different terms of expression.

XV.—*Yield of wheat, in bushels per acre, in seven 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 8. Oats on fallow, wheat fall plowed, fallow.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
n Basin, Mont	1909	34.8	33.1	31.0	33.3	38.0	a 40.3
nson, N. Dak	1908	a 35.8	35.0	35.0	18.8	33.0	20.5
o	1909	a 39.8	39.7	37.3	34.3	37.7	35.0
ey, N. Dak	1907	a 16.7	13.2	12.6	10.5	11.8	8.5
o	1908	a 24.0	15.8	20.8	15.7	19.5	10.3
o	1909	a 33.0	32.6	32.5	28.5	29.8	26.6
more, S. Dak	1906	26.7	27.3	25.5	25.0	a 31.7	25.0
o	1907	21.5	29.0	27.2	29.0	a 33.3	32.7
o	1908	24.3	25.2	25.7	21.8	a 29.0	27.5
fourche, S. Dak	1909	29.4	23.9	29.9	29.7	31.4	a 33.2
a Platte, Nebr	1907	22.3	23.7	20.7	24.2	26.0	a 28.3
o	1908	28.6	24.0	27.7	31.3	a 42.2	31.3
o	1909	21.7	17.2	a 24.3	16.8	27.2	16.8
n, Colo	1909	a 25.0	20.8	19.2	10.6	18.2	10.9
, Kans	1908	3.7	1.5	3.9	a 6.7	4.1	4.2
en City, Kans	1909	1.0	4.0	2.2	.9	a 6.6	3.8
art, Tex	1909	.0	.0	.0	.0	a 7.7	.0
rillo, Tex	1908	8.3	8.0	8.5	13.2	a 16.5	13.7
Do	1909	.0	.0	.0	.0	9.5	.0
Average	....	20.87	19.68	20.21	18.44	23.85	19.40
Average from continuous cropping	....	17.39	17.39	17.39	17.39	17.39	17.39
Gain per acre by rotation compared with continuous cropping	....	3.48	2.29	2.82	1.05	6.48	2.01

Station.	Year.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
					Gain.	Loss.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
dith Basin, Mont	1909	31.6	34.59	33.0	1.59	....
ckinson, N. Dak	1908	18.7	28.11	24.3	3.81	....
Do	1909	30.7	36.36	26.8	9.56	....
igsley, N. Dak	1907	4.2	11.07	4.1	6.97	....
Do	1908	13.5	17.09	13.3	3.79	....
Do	1909	25.8	29.73	28.3	1.43	....
ighmore, S. Dak	1906	25.7	26.70	....	....	....
Do	1907	24.5	28.17	28.8	....	0.63
Do	1908	24.2	25.34	26.3	....	.96
ellefourche, S. Dak	1909	26.1	29.09	23.8	5.29	....
orth Platte, Nebr	1907	20.8	23.71	24.5	....	.79
Do	1908	17.5	28.94	22.7	6.24	....
Do	1909	16.7	20.10	23.0	....	2.90
kron, Colo	1909	14.3	17.00	14.3	2.70	....
ays, Kans	1908	2.2	3.76	1.2	2.56	....
arden City, Kans	1909	2.5	3.00	2.1	.90	....
alhart, Tex	1909	.0	1.10	.0	1.10	....
marillo, Tex	1808	5.3	10.50	17.0	....	6.50
Do	1909	.0	1.36	.0	1.36	....
Average	....	16.01	19.78	....	....	....
Average from continuous cropping	....	17.39	17.39	17.39	....	....
Gain (or loss) per acre by rotation compared with continuous cropping	....	− 1.39	2.39	....	....	....

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a Rotation giving the best yield of wheat.

TABLE XVI.—*Farm value of wheat, in dollars and cents per acre, in seven 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 8. Oats on fallow, wheat fall plowed, fallow.
Judith Basin, Mont	1909	$20.88	$19.88	$18.60	$19.98	$20.80	[illegible]
Dickinson, N. Dak	1908	21.84	21.00	21.00	11.28	19.80	[illegible]
Do	1909	23.88	23.82	22.38	20.58	22.62	[illegible]
Edgeley, N. Dak	1907	10.02	7.92	7.56	6.30	7.08	[illegible]
Do	1908	14.40	9.48	12.48	9.42	11.70	[illegible]
Do	1909	19.80	19.56	19.50	17.10	17.88	[illegible]
Highmore, S. Dak	1906	16.02	16.38	15.30	15.00	19.02	[illegible]
Do	1907	12.90	17.40	16.32	17.40	19.98	[illegible]
Do	1908	14.58	15.12	15.42	13.08	17.40	[illegible]
Bellefourche, S. Dak	1909	17.64	14.34	17.94	17.82	18.84	[illegible]
North Platte, Nebr	1907	13.38	14.22	12.42	14.52	15.60	[illegible]
Do	1908	17.16	14.40	16.62	18.78	25.32	[illegible]
Do	1909	13.02	10.32	14.58	10.08	16.32	[illegible]
Akron, Colo	1909	15.00	12.48	11.52	6.36	10.92	[illegible]
Hays, Kans	1908	2.22	.90	2.34	4.02	2.46	[illegible]
Garden City, Kans	1909	.60	2.40	1.32	.54	3.96	[illegible]
Dalhart, Tex	1909	.00	.00	.00	.00	4.62	[illegible]
Amarillo, Tex	1908	4.98	4.80	5.10	7.92	9.90	[illegible]
Do	1909	.00	.00	.00	.00	5.70	[illegible]
Average		12.52	11.81	12.13	11.06	14.31	11.64

Station.	Year.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
					Gain.	Loss.
Judith Basin, Mont	1909	$18.96	$20.75	$19.80	$0.95	
Dickinson, N. Dak	1908	11.22	16.87	14.58	2.29	
Do	1909	18.42	21.81	16.08	5.73	
Edgeley, N. Dak	1907	2.52	6.64	2.46	4.18	
Do	1908	8.10	10.25	7.98	2.27	
Do	1909	15.48	17.90	16.98	.92	
Highmore, S. Dak	1906	15.42	16.02			
Do	1907	14.70	16.90	17.28		[illegible]
Do	1908	14.52	15.20	15.78		[illegible]
Bellefourche, S. Dak	1909	15.66	17.45	14.28	3.17	
North Platte, Nebr	1907	12.48	14.23	14.70		[illegible]
Do	1908	10.50	17.33	13.62	3.71	
Do	1909	10.00	12.06	13.80		[illegible]
Akron, Colo	1909	8.58	10.20	8.58	1.62	
Hays, Kans	1908	1.33	2.26	.72	1.54	
Garden City, Kans	1909	1.50	1.80	1.26	.54	
Dalhart, Tex	1909	.00	.66	.00	.66	
Amarillo, Tex	1908	3.18	6.30	10.20		[illegible]
Do	1909	.00	.81	.00	.81	
Average		9.61	[a] 11.87	[b] 10.45	[b] 1.19	

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[a] Average of 19 crops.

[b] Average of 18 crops.

XVII.—*Yield of oats, in bushels per acre, in nine 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
h Basin, Mont	1909	68.1	63.1	61.5	[a] 74.1	67.1	57.8	74.0
nson, N. Dak	1908	35.3	52.5	38.9	[a] 67.2	39.4	44.7	60.9
Do	1909	64.4	60.6	62.5	72.5	63.8	61.9	70.3
ley, N. Dak	1907	25.9	29.7	30.5	28.8	27.5	[a] 32.5	24.8
Do	1908	26.3	20.6	16.9	23.4	[a] 33.4	15.9	24.7
Do	1909	64.0	63.7	[a] 66.5	63.7	63.7	60.3	60.9
more, S. Dak	1906	45.3	38.9	47.2	61.6	46.6	53.8	57.5
Do	1907	46.9	41.6	45.3	48.4	55.0	49.4	43.8
Do	1908	28.8	36.9	29.7	35.6	27.8	36.3	40.0
fourche, S. Dak	1909	55.6	42.5	53.6	75.0	51.6	65.6	58.8
h Platte, Nebr	1907	26.9	32.3	30.6	40.6	31.2	23.1	35.7
Do	1908	60.3	36.9	60.3	54.3	54.7	49.1	60.3
Do	1909	23.1	28.1	18.3	22.5	19.1	19.7	[a] 35.0
on, Colo	1909	25.6	18.3	18.8	21.3	16.7	20.8	25.6
s, Kans	1908	28.5	26.0	20.1	16.0	22.8	[a] 35.5	15.2
den City, Kans	1909	3.0	1.3	.0	2.9	3.3	3.1	3.8
hart, Tex	1909	.0	.0	.0	.0	.0	.0	.0
arillo, Tex	1908	28.1	23.4	27.5	22.8	24.4	31.3	21.3
Do	1909	10.0	.0	17.8	.0	15.3	.0	.0
Average	....	35.06	32.44	34.00	38.46	34.92	34.78	37.50
Average from continuous cropping	....	30.16	30.16	30.16	30.16	30.16	30.16	30.16
Gain per acre by rotation compared with continuous cropping	....	4.90	2.28	3.84	8.30	4.76	4.62	7.34

Station.	Year.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
dith Basin, Mont	1909	66.2	70.7	65.8	75.3	....	9.5
ickinson, N. Dak	1908	60.9	50.6	50.0	48.4	1.4	....
Do	1909	[a] 74.7	71.3	66.9	55.9	11.0	....
dgeley, N. Dak	1907	30.9	5.6	26.2	21.3	4.9	....
Do	1908	20.9	16.9	22.1	16.9	5.2	....
Do	1909	56.2	58.7	62.0	57.5	4.5	....
ighmore, S. Dak	1906	[a] 83.4	56.9	54.6	....	....	....
Do	1907	[a] 57.8	47.5	48.4	45.3	3.1	....
Do	1908	[a] 46.6	41.6	35.9	34.4	1.5	....
Bellefourche, S. Dak	1909	[a] 85.2	62.2	61.1	48.8	12.3	....
North Platte, Nebr	1907	[a] 40.9	33.4	32.7	30.0	2.7	....
Do	1908	[a] 91.5	48.2	59.6	34.4	25.1	....
Do	1909	....	27.5	21.5	31.3	....	9.8
Akron, Colo	1909	[a] 28.3	17.5	21.4	21.1	.3	....
Hays, Kans	1908	28.8	19.1	23.5	1.3	21.2	....
Garden City, Kans	1909	[a] 5.8	2.3	2.8	1.0	1.8	....
Dalhart, Tex	1909	[a] 10.0	.0	1.1	.0	1.0	....
Amarillo, Tex	1908	[a] 33.4	22.5	26.1	20.0	6.1	....
Do	1909	[a] 25.6	.0	7.7	.0	7.7	....
Average	....	44.58	34.34	36.27	....	....	....
Average from continuous cropping	....	30.16	30.16	30.16	....	....	....
Gain per acre by rotation compared with continuous cropping	....	14.42	4.18	6.11	....	....	....

[a] Rotation giving the best yield of oats.

TABLE XVIII.—*Farm value of oats, in dollars and cents per acre, in nine 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed. oats spring plowed. corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed. corn fall plowed.	No. 4. Oats disked. wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed. fallow.	No. 6. Barley disked, oats fall plowed. corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.
Judith Basin, Mont	1909	$20.43	$18.93	$18.45	$22.23	$20.13	$17.34	[illegible]
Dickinson, N. Dak	1908	10.59	15.75	11.67	20.16	11.82	13.41	[illegible]
Do	1909	19.32	18.18	18.75	21.74	19.14	18.57	[illegible]
Edgeley, N. Dak	1907	7.77	8.91	9.15	8.64	8.25	9.75	[illegible]
Do	1908	7.89	6.18	5.07	7.02	10.02	4.77	[illegible]
Do	1909	19.20	19.11	19.95	19.11	19.11	18.09	[illegible]
Highmore, S. Dak	1906	13.59	11.64	14.16	18.48	13.98	16.14	[illegible]
Do	1907	14.07	12.48	13.59	14.52	16.50	14.82	[illegible]
Do	1908	8.64	11.07	8.91	10.68	8.34	10.89	[illegible]
Bellefourche, S. Dak	1909	16.68	12.75	16.08	22.50	15.48	19.68	[illegible]
North Platte, Nebr	1907	8.07	9.69	9.18	12.18	9.36	6.93	[illegible]
Do	1908	18.09	11.07	18.09	16.29	16.41	14.73	[illegible]
Do	1909	6.93	8.43	5.49	6.75	5.73	5.91	[illegible]
Akron, Colo	1909	7.68	5.49	5.64	6.39	5.01	6.24	[illegible]
Hays, Kans	1908	8.55	7.80	6.03	4.80	6.84	10.65	[illegible]
Garden City, Kans	1909	.90	.39	.00	.87	.99	.93	[illegible]
Dalhart, Tex	1909	.00	.00	.00	.00	.00	.00	[illegible]
Amarillo, Tex	1908	8.43	7.02	8.25	6.84	7.32	9.39	[illegible]
Do	1909	3.00	.00	5.34	.00	4.59	.00	[illegible]
Average	....	10.52	9.73	10.20	11.54	10.47	10.43	11.35

Station.	Year.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed. corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
Judith Basin, Mont	1909	$19.86	$21.21	$20.09	$22.59	....	$2.50
Dickinson, N. Dak	1908	18.27	15.18	15.01	14.52	$0.49	....
Do	1909	22.41	21.39	20.07	16.77	3.30	....
Edgeley, N. Dak	1907	9.27	1.68	7.87	6.39	1.48	....
Do	1908	6.27	5.07	6.63	5.07	1.56	....
Do	1909	16.86	17.61	18.59	17.25	1.34	....
Highmore, S. Dak	1906	25.02	17.07	16.37	....	....	....
Do	1907	17.34	14.25	14.52	13.59	.93	....
Do	1908	13.98	12.48	10.78	10.32	.46	....
Bellefourche, S. Dak	1909	25.56	18.66	18.34	14.64	3.70	....
North Platte, Nebr	1907	12.27	10.02	9.82	9.00	.82	....
Do	1908	27.45	14.46	17.19	10.32	6.87	....
Do	1909	.00	8.25	6.44	9.39	....	2.95
Akron, Colo	1909	8.49	5.25	6.43	6.33	.10	....
Hays, Kans	1908	8.64	5.73	7.07	.39	6.68	....
Garden City, Kans	1909	1.74	.69	.85	.30	.55	....
Dalhart, Tex	1909	3.00	.00	.33	.00	.33	....
Amarillo, Tex	1908	10.02	6.75	7.82	6.00	1.82	....
Do	1909	7.68	.00	2.29	.00	2.29	....
Average	....	13.37	10.30	[a]10.87	[b]9.05	[b]1.52	....

[a] Average of 19 crops.

[b] Average of 18 crops.

XIX.—*Yield of barley, in bushels per acre, in two 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Corn spring plowed, barley spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Basin, Mont	1909	42.7	39.1	40.9	45.2	....	4.3
nson, N. Dak	1908	45.6	34.4	40.0	33.5	6.5	....
o	1909	53.8	49.2	51.5	39.8	11.7	....
ey, N. Dak	1907	18.3	10.6	14.5	10.2	4.3	....
o	1908	31.9	26.0	28.9	25.0	3.9	....
o	1909	33.1	32.7	32.9	27.0	5.9	....
more, S. Dak	1906	37.7	29.2	33.5	....	....	....
o	1907	25.0	28.3	26.6	30.2	....	3.6
o	1908	30.0	29.9	29.9	29.8	.1	....
fourche, S. Dak	1909	47.1	28.1	37.6	23.8	13.8	....
Platte, Nebr	1907	30.6	40.2	35.4	39.0	....	3.6
o	1908	24.9	22.3	23.6	19.6	4.0	....
o	1909	21.5	18.5	20.0	....	....	....
n, Colo	1909	24.9	22.2	23.6	19.7	3.9	....
s, Kans	1908	12.3	9.2	10.8	5.8	5.0	....
en City, Kans	1909	5.1	5.7	5.4	2.4	3.0	....
art, Tex	1909	.0	.0	.0	.0	.0	....
rillo, Tex	1908	7.5	8.1	7.8	7.9	....	.1
Do	1909	.0	.0	.0	.0	.0	....
Average	....	25.9	22.83	24.4	21.1	3.0	....

BLE XX.—*Farm value of barley, in dollars and cents per acre, in two 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	Average yield.	Value of continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
dith Basin, Mont	1909	$16.23	$14.86	$15.54	$17.17	....	$1.63
ckinson, N. Dak	1908	17.33	13.07	15.20	12.73	$2.47	....
Do	1909	20.44	18.70	19.57	15.12	4.45	....
dgeley, N. Dak	1907	6.95	4.03	5.49	3.88	1.61	....
Do	1908	12.12	9.88	11.00	9.50	1.50	....
Do	1909	12.58	12.43	12.51	10.26	2.25	....
ighmore, S. Dak	1906	14.33	11.10	12.71	....	....	....
Do	1907	9.50	10.75	10.13	11.47	....	1.34
Do	1908	11.40	11.36	11.38	11.32	.06	....
ellefourche, S. Dak	1909	17.90	10.68	14.29	9.04	5.25	....
orth Platte, Nebr	1907	11.63	15.28	13.45	14.82	....	1.37
Do	1908	9.46	8.47	8.97	7.44	1.53	....
Do	1909	8.17	7.03	7.60	....	....	....
kron, Colo	1909	9.46	8.44	8.95	7.48	1.47	....
ays, Kans	1908	4.67	3.50	4.08	2.20	1.88	....
arden City, Kans	1909	1.94	2.17	2.06	.91	1.15	....
Delhart, Tex	1909	.00	.00	.00	.00	.00	....
Amarillo, Tex	1908	2.85	3.08	2.96	3.00	....	.04
Do	1909	.00	.00	.00	.00	.00	....
Average	....	9.84	8.67	9.26	8.02	1.13	....

Table XXI is a summary of preceding tables and shows that the average yields obtained from all rotations were considerably higher than from continuous cropping by ordinary methods.

As we have already shown that neither summer tillage and alternate cropping nor continuous cropping with moisture-conservation methods gave as good net results as continuous cropping by ordinary methods, we will continue to use the yields obtained by ordinary methods as a basis for comparison. This table shows that the average yields for all tests of all rotations were better than the continuous cropping yields for all three crops of wheat, oats, and barley. It also shows that the averages of all tests of each rotation taken separately were better for all crops, with one exception, than continuous cropping, the one exception noted being wheat in rotation No. 9, where it was sown on spring-plowed land after oats. The preceding tables show these same facts in more detail. It would seem, then, that our evidence was quite conclusive as to the superiority of crop rotation over any of the other methods which have so far been discussed.

TABLE XXI.—*Summary of foregoing tables, showing average yields per acre and average farm values per acre.*

CONTINUOUS CROPPING AND ALTERNATE CROPPING AND SUMMER TILLAGE.

Plat and cropping method.	Wheat.		Oats.		Barley.	
	Bush.		*Bush.*		*Bush.*	
C or D. Summer tillage and alternate cropping (1 crop in 2 years)	22.5	$13.50	44.1	$13.23	30.7	$11.67
B. Continuous cropping by moisture-conservation methods	16.5	9.90	30.5	9.15	22.9	8.70
A. Continuous cropping by ordinary methods	17.4	10.44	30.2	9.06	21.1	8.02

ROTATIONS.

Crop.		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Wheat	bushels	20.87	19.68	20.21	18.44	23.85	....	....	19.40	16.01
	value	$12.52	$11.81	$12.13	$11.06	$14.31	....	....	$11.64	$9.61
Oats	bushels	35.06	32.44	34.00	38.46	34.92	34.78	37.50	44.58	34.34
	value	$10.52	$9.73	$10.20	$11.54	$10.47	$10.43	$11.25	$13.37	$10.30
Barley	bushels	....	....	....	....	....	25.90	22.83	....	....
	value	....	....	....	....	....	$9.84	$8.67	....	....

Item of comparison.	Wheat.		Oats.		Barley.	
	Bush.		*Bush.*		*Bush.*	
Average yield and value per acre from rotations	19.8	$11.87	36.3	$10.89	24.4	$9.26
Average increase in yield compared with continuous cropping by ordinary methods	2.4	1.43	6.1	1.83	3.3	1.24

MPARISON OF THE RELATIVE FARM VALUE OF CROPS OF WHEAT, OATS, AND BARLEY PRODUCED BY EACH OF THE NINE ROTATIONS AND BY CONTINUOUS CROPPING.

THE TABULAR SUMMARY.

In Tables XXII and XXIII have been brought together in con- ensed form much of the data contained in the foregoing tables. able XXII gives the farm value per acre for wheat and oats or arley and oats for each rotation. The figures given in the respective olumns of Table XXIII for each rotation were obtained by subtract- g the corresponding figures for the farm values of each test of ontinuous cropping, as given in Table V, from the farm values for ach test of each rotation as given in Table XXII. In these com- arisons the average farm value per acre for wheat and oats has een used for rotations Nos. 1, 2, 3, 4, 5, 8, and 9, and for barley and ats in rotations Nos. 6 and 7—the basis of valuation, as in all other ables, being 60 cents for wheat, 30 cents for oats, and 38 cents for arley. The second column from the right-hand side of the table ives the loss or gain in dollars per acre of the best rotation, except os. 5 and 8, as compared with continuous cropping. The reason or excepting Nos. 5 and 8 is that they are both fallow rotations and re therefore not strictly comparable with the other rotations of his series where a crop is grown every year. This best rotation is printed in black-faced type so as to be readily recognized at a glance. At the foot of each column is given the average for all tests of the respective rotations. Just below these averages are given their quivalents in bushels per acre of wheat, oats, and barley. It must be constantly borne in mind that the farm values are all based upon wheat at 60 cents, oats at 30 cents, and barley at 38 cents. These prices are at least 50 per cent too low to meet present price conditions. In order, therefore, to meet these conditions, all the farm values expressed in dollars and cents should be multiplied by 1.5, while bushels per acre would, of course, remain the same.

We find from consulting the figures given in this table that all the rotations except No. 9 gave better average results for all the tests than continuous cropping. We also find that the average results for all rotations in each test were better than continuous cropping except at Judith Basin, Mont., 1909; North Platte, Nebr., 1909; and Amarillo, Tex., 1908.

At Judith Basin the crops were all grown on virgin prairie, broken in 1907 and first cropped in 1908. The season of 1909 was especially favorable, so that very large crops were raised by all methods. The slight difference in favor of continuous cropping was therefore of little or no significance. At North Platte the results were very slightly in favor of rotation in 1907 and very markedly so in 1908. The average results of the three years were therefore in favor of rotation, so the results of 1909 can not be considered of great significance. They were due to the fact that a severe freeze about the first of May, followed by high winds, injured the crops on those fields that had had the best tillage and had consequently produced the most vigorous growth more than it did those on the poorer tilled fields where the growth was less advanced. This is not an infrequent occurrence throughout the Great Plains, but it can not be used as a reason for practicing continuous cropping instead of crop rotation. The crops at Amarillo, Tex., were so near a practical failure that the fact that continuous cropping gave slightly better results can not be considered of great significance. It may therefore be safely asserted that the net results of all the tests were strongly in favor of rotation. This becomes more apparent when we consider that the best rotation in the test gave better results than continuous cropping in all except three instances, and the average results showed a difference in favor of rotation amounting to $2.38 per acre; or calculated in bushels of wheat, oats, and barley, 3.91, 7.93, and 6.26 bushels per acre, respectively.

At first sight it might appear that there was little uniformity in the rotation giving the best average results in all the tests or in the ones giving the best results at any given station where two or more years' results have been obtained. A more careful consideration will show, however, that some general uniformity in results is indicated. In just half the tests either rotations Nos. 1 or 6 gave the best results. These two rotations are identical except that in No. 1 wheat was sown on disked corn stubble and in No. 6 barley was substituted for the wheat. The other barley rotation, No. 7, gave the best results in three tests. Nos. 3 and 4 gave the best results in two tests each, while No. 2 gave the best results in only one test.

Rotation No. 9 failed to give the best results in any test. This fact is very significant, as it brings to notice an important feature of crop rotation. This is, that one sequence may give the best results at a station when the plowing is done at one time of year, while the opposite sequence gives the best results when the plowing is done at another time. It seems that the oats-wheat-corn sequence makes a bad combination with spring plowing at all the stations. It seems likely that further investigation will show that there are other combinations which are to be avoided.

When we come to a consideration of the rotation which has given ne best results at those stations where two or more tests have been nade, we find less difficulty in reconciling the seeming diversity of esults.

At Dickinson, N. Dak., rotation No. 1 gave the best results in 1908 nd No. 2 in 1909. A change of 60 cents in the relative farm values er acre in 1909 would have made No. 2 the best both years. It is uite probable that a rotation of wheat on disked corn stubble, oats n spring plowing, and corn on spring plowing would give better esults than either No. 1 or No. 2 at this station.

At Edgeley, N. Dak., rotation No. 1 gave the best results in 1907 nd 1908, while in 1909 No. 3 was best. The difference between No. l and No. 3 in 1909 was, however, only 23 cents per acre. These two rotations differ only in that in No. 1 the corn stubble is disked and in No. 3 it is plowed. It may therefore be inferred that No. 1 will give the best average results at this station.

At Highmore, S. Dak., rotation No. 6 gave the best results one year and No. 7 the next. These are both barley rotations. It may therefore be inferred that barley is a profitable crop there, and that neither the sequence nor the time of plowing is of great importance in a 3-year rotation of corn, oats, and barley.

At North Platte, Nebr., a different rotation gave the best results in each of the three tests. The results in the 1909 tests were so affected by adverse weather conditions in May as to have little significance. In 1907 No. 4 and in 1908 No. 1 gave the best results. These two rotations differ only in sequence. In both No. 1 and No. 4 grain was sown on disked corn stubble, and the corn and other small-grain crop were on fall plowing. It would therefore seem that at this station disked corn stubble for one of the small-grain crops and fall plowing for corn and other small-grain crops are the best methods of preparation and that sequence is of relatively small importance.

At Amarillo the crops all suffered so severely from drought in 1909 that the discrepancies in the results of the two years are not significant.

Comparisons of the several rotations will be made in discussing the tables which follow.

TABLE XXII.—*Average farm value, in dollars and cents, per acre, of nine 3-year rotations.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Wheat on fallow, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.
Judith Basin, Mont.	1909	$20.66	$19.40	$18.53	$21.11	$21.47	$16.79
Dickinson, N. Dak.	1908	16.03	18.37	16.33	15.72	15.81	15.57
Do.	1909	21.60	21.00	20.57	21.17	20.88	19.59
Edgeley, N. Dak.	1907	8.90	8.42	8.35	7.47	7.66	8.35
Do.	1908	11.14	7.83	8.78	8.22	10.86	8.45
Do.	1909	19.50	19.33	19.72	18.10	18.50	15.33
Highmore, S. Dak.	1906	14.81	14.01	14.73	16.74	16.50	15.24
Do.	1907	13.48	14.94	14.96	15.96	18.24	12.16
Do.	1908	11.61	13.10	12.16	11.88	12.87	11.14
Bellefourche, S. Dak.	1909	17.16	13.55	17.01	20.16	17.16	16.79
North Platte, Nebr.	1907	10.73	11.96	10.80	13.35	12.48	9.28
Do.	1908	17.62	12.73	17.36	17.54	20.87	[illegible]
Do.	1909	9.98	9.37	10.04	8.41	11.02	7.06
Akron, Colo.	1909	11.34	8.99	8.58	6.38	7.96	7.85
Hays, Kans.	1908	5.39	4.35	4.19	4.41	4.65	7.06
Garden City, Kans.	1909	.75	1.39	.66	.70	2.48	1.44
Dalhart, Tex.	1909	.00	.00	.00	.00	2.31	.00
Amarillo, Tex.	1908	6.71	5.91	6.67	7.38	8.61	6.12
Do.	1909	1.50	.00	2.67	.00	5.14	.00
Average.	....	11.52	10.77	11.16	11.30	12.39	10.14

Station.	Year.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Gain or loss of rotation compared with continuous cropping.
Judith Basin, Mont.	1909	$18.53	$22.02	$20.08	$19.84	$20.91	−$1.07
Dickinson, N. Dak.	1908	15.67	15.29	13.20	15.75	14.34	1.41
Do.	1909	19.89	21.70	19.90	20.69	16.32	4.37
Edgeley, N. Dak.	1907	5.74	7.19	2.10	7.13	4.59	2.54
Do.	1908	8.65	6.22	6.59	8.53	6.70	1.83
Do.	1909	15.35	16.41	16.54	17.64	16.36	1.28
Highmore, S. Dak.	1906	14.17	20.01	16.25	15.83	....	....
Do.	1907	11.95	18.48	14.48	14.96	14.79	.17
Do.	1908	11.68	15.24	13.50	12.58	12.55	.03
Bellefourche, S. Dak.	1909	14.16	22.74	17.16	17.54	13.88	3.66
North Platte, Nebr.	1907	12.99	14.63	11.25	11.94	11.86	.08
Do.	1908	13.28	23.11	12.48	16.34	11.29	5.05
Do.	1909	8.78	5.04	9.13	8.76	11.10	− 2.35
Akron, Colo.	1909	8.06	7.52	6.92	8.18	7.34	.84
Hays, Kans.	1908	4.03	5.58	3.52	4.86	.72	4.14
Garden City, Kans.	1909	1.65	2.01	1.10	1.35	.74	.61
Dalhart, Tex.	1909	.00	1.50	.00	.42	.00	.42
Amarillo, Tex.	1908	4.73	9.12	4.96	6.68	7.30	− .62
Do.	1909	.00	3.84	.00	1.46	.00	1.46
Average.	....	9.97	12.51	9.95	[a]11.08	[b]9.40	1.35

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[a] Average of 19 crops.

[b] Average of 18 crops.

XXIII.—*Gain or loss of each rotation for each test as compared with continuous cropping by ordinary methods.*

plus sign indicates gain in favor of rotation and the minus sign loss—in terms of dollars and cents acre for wheat and oats or barley and oats in each rotation. The best rotation, excepting Nos. 5 8, each of which has one fallow year and is therefore not strictly comparable with the others, is ated in black-faced type.]

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.
th Basin, Mont	1909	−$0.54	−$1.80	−$2.67	**−$0.09**	+$0.27	−$3.09
kinson, N. Dak	1908	+ 1.49	**+ 3.82**	+ 1.78	+ 1.17	+ 1.26	+ 1.75
Do	1909	**+ 5.18**	+ 4.58	+ 4.15	+ 4.75	+ 4.46	+ 3.56
eley, N. Dak	1907	**+ 4.47**	+ 4.00	+ 3.93	+ 3.05	+ 3.21	+ 3.22
Do	1908	**+ 4.62**	+ 1.31	+ 2.26	+ 1.70	+ 4.34	+ 1.17
Do	1909	+ 2.38	+ 2.22	**+ 2.61**	+ .99	+ 1.39	+ 1.49
hmore, S. Dak	1907	− 1.95	− .49	− .47	+ .53	+ 2.81	**− .37**
Do	1908	− 1.44	+ .05	− .89	− 1.17	− .18	+ .32
efourche, S. Dak	1909	+ 2.70	− .91	+ 2.55	+ 5.70	+ 2.70	**+ 6.95**
th Platte, Nebr	1907	− 1.12	+ .11	− 1.05	**+ 1.50**	+ .63	− 2.63
Do	1908	**+ 5.65**	+ .76	+ 5.39	+ 5.57	+ 8.90	+ 3.21
Do	1909	− 1.62	− 2.22	− 1.55	− 3.18	− .57	− 2.35
on, Colo	1909	**+ 3.88**	+ 1.54	+ 1.13	− 1.07	+ .51	+ .94
ys, Kans	1908	+ 4.83	+ 3.80	+ 3.64	+ 3.86	+ 4.10	**+ 6.37**
den City, Kans	1909	− .03	+ .61	− .12	− .08	+ 1.70	+ .84
hart, Tex	1909	+ .00	+ .00	+ .00	+ .00	+ 2.31	+ .00
arillo, Tex	1908	− 1.39	− 2.19	− 1.43	− .72	+ .51	**+ 1.62**
Do	1909	+ 1.50	+ .00	**+ 2.67**	+ .00	+ 5.14	+ .00
Average		+ 1.59	+ .84	+ 1.22	+ 1.25	+ 2.41	+ 1.32
ual to wheat at 60 cents....bu		2.65	1.40	2.03	2.08	4.00	2.20
ual to oats at 30 cents.....do		5.30	2.80	4.06	4.16	8.00	4.40
ual to barley at 38 cents...do		4.19	2.21	3.21	3.29	6.35	3.47

Station.	Year.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	No. 8. Oats fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average gain or loss of all rotations compared with continuous cropping.	Difference in favor of the best rotation except Nos. 5 and 8 compared with continuous cropping.
dith Basin, Mont	1909	−$1.35	+$0.82	−$1.12	−$1.06	−$0.09
ickinson, N. Dak	1908	+ 2.05	+ .74	− 1.35	+ 1.41	+ 3.82
Do	1909	+ 3.95	+ 5.28	+ 3.48	+ 4.36	+ 5.18
dgeley, N. Dak	1907	+ .61	+ 2.77	− 2.32	+ 2.55	+ 4.47
Do	1908	+ 1.37	− .30	+ .07	+ 1.84	+ 4.62
Do	1909	+ 1.60	− .70	− .57	+ 1.27	+ 2.61
ighmore, S. Dak	1907	− .58	+ 3.05	− .95	+ .17	− .37
Do	1908	**+ .86**	+ 2.19	+ .45	+ .02	+ .86
ellefourche, S. Dak	1909	+ 2.32	+ 8.28	+ 2.70	+ 3.66	+ 6.95
orth Platte, Nebr	1907	+ 1.08	+ 2.78	− .60	+ .08	+ 1.50
Do	1908	+ 4.40	+11.14	+ .51	+ 5.06	+ 5.65
Do	1909	**− .62**	− 6.55	− 2.46	− 2.35	− .62
kron, Colo	1909	+ 1.15	+ .07	− .53	+ .85	+ 3.88
ays, Kans	1908	+ 2.74	+ 5.03	+ 2.97	+ 4.15	+ 6.37
arden City, Kans	1909	**+ 1.05**	+ 1.23	+ .32	+ .61	+ 1.05
alhart, Tex	1909	+ .00	+ 1.50	+ .00	+ .42	+ .00
Amarillo, Tex	1908	+ .23	+ 1.02	− 3.14	− .61	+ 1.62
Do	1909	+ .00	+ 3.84	+ .00	+ 1.46	+ 2.67
Average		+ 1.16	+ 2.34	− .14	+ 1.35	+ 2.79
Equal to wheat at 60 cents....bu		1.93	3.89	− 0.23	2.25	4.65
Equal to oats at 30 cents......do		3.87	7.80	− 1.46	4.50	9.30
Equal to barley at 38 cents....do		3.06	6.16	− 1.37	3.55	7.34

DISKED CORN STUBBLE BETTER THAN SUMMER TILLAGE FOR SPRING WHEAT AND OATS.

Table XXIV gives a comparison between the effects of summer tillage and disked corn stubble as a preparation for wheat and oats.

Rotation No. 1—corn on fall plowing, wheat on disked corn stubble, oats on fall plowing—is identical with No. 4 except that the sequence of the wheat and oats has been changed. Rotation No. 5—summer tillage, wheat on summer-tilled land, oats on fall plowing—is identical with No. 8, except that the sequence of the wheat and oats has been changed. We have therefore two pairs of rotations, 1 and 4 and 5 and 8. In both rotations of the first pair (1 and 4) corn is raised. In one of them (1) wheat is sown on the disked corn stubble. In the other (4) the oats are sown on the disked corn stubble. In the second pair (5 and 8) the land is summer tilled instead of being planted to corn. In one of these (5) wheat is sown on the summer-tilled land. In the other (8) oats are sown on the summer-tilled land.

A comparison of the average farm value per acre of these two pairs of rotations will give the relative merits of disked corn stubble and summer tillage as a preparation for both wheat and oats.

In the column headed "No. 1" is given the average farm value per acre of the two grain crops, wheat and oats, for each test. These values are calculated at 60 cents per bushel for wheat and 30 cents per bushel for oats for rotation No. 1. In the column headed "No. 4" are given the same data for rotation No. 4. In the next column to the right are given the average farm values per acre of the wheat and oats in the two corn rotations (1 and 4). In the columns headed "No. 5" and "No. 8" are given the same data for rotations Nos. 5 and 8, respectively. In the next column are given the average farm values per acre of the wheat and oats in the two summer-tilled rotations (5 and 8). In the next two columns are given the differences in farm value per acre between the average of the two pairs 1 and 4 and 5 and 8, which represent the gain in favor of summer tillage or disked corn stubble, as the case may be, for each test. In these comparisons the value of the corn crop is not included, the oat and wheat crops alone being considered. It is found that in twelve tests the summer-tilled rotations gave better average farm values per acre for the two grain crops than did the corn rotations, while in seven tests the corn rotations gave better average farm values for wheat and oats than the summer-tilled rotations, the average farm value per acre in favor of summer tillage being only $1.04 per acre and the greatest gain of summer tillage over disked corn stubble being only $4.41 per acre.

The cost of the summer tillage was fully equal to, if not more than, the cost of raising the corps of corn. Therefore, the total value of the crops of corn raised should be credited to the corn rotations. Although the yields from the corn plats, as previously explained, were much less satisfactory than those from the small grain plats, we have given them in this instance. In four tests, Judith Basin, Mont., Dickinson, N. Dak., 1908, and Edgeley, N. Dak., 1907 and 1908, the corn did not mature on account of the variety used not being early enough. In two other tests, Garden City, Kans., and Dalhart, Tex., no grain was produced on account of severe drought. In these sts the yields of the fodder alone have been given. At High- no record was kept of the fodder, so only the grain yields are n. The record is therefore incomplete and unsatisfactory, but sufficient to show the superiority of the corn rotations over the ner-tilled rotations.

e value of the fodder was calculated at $3 per ton. It is possible this is too high for some localities where wild hay could be ob- ed for the cost of cutting, stacking, and hauling; on the other l it was probably too low where hay was scarce and high on ac- nt of drought. The average farm value of hay for ten years in four States of North Dakota, South Dakota, Nebraska, and sas has been $4.78 per ton. On this basis corn fodder would be th at least $3. The average farm value per acre of the grain e of the corn crop at the twelve stations where the corn matured $10 per acre, calculated at 39 cents per bushel. The average n value per acre of fodder in the sixteen tests where a record was t was $4.67. At three of the tests where corn failed to mature, the eat and oats gave better yields on the corn stubble than on the nmer tillage. This leaves only three tests—Judith Basin, Mont., rden City, Kans., and Dalhart, Tex.—where the gain was not in or of the corn rotations. At Garden City, Kans., and Dalhart, x., the entire crops of wheat, oats, and corn were a practical failure en on the summer-tilled land, so these tests may be discarded as lecisive. The balance would therefore be in favor of the corn tations in all the decisive tests, except Judith Basin, if no value atever were placed upon the corn fodder. A valuation of even cents per ton for the fodder would turn the balance in favor of the rn rotation at Judith Basin.

In the final right-hand column of the table are given the net average ins per acre of the corn rotations over the summer-tilled rotations, cluding both the grain and fodder of the corn crop. These figures ere obtained by adding half the average value of the corn crops the average value of the wheat and oats in the corn rotations and btracting the average value of the wheat and oat crops in the mmer-tilled rotations.[a]

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[a] The reason for adding one-half instead of the whole of the average farm value per cre of the two corn crops to the average farm value per acre of the two wheat and two at crops in the corn rotations (1 and 4) is as follows: There are twice as many acres f wheat and oats, taken together, as there are either of corn or of summer-tilled land, espectively, in each of the two pairs of rotations. One-half of the average farm value f the two corn crops should therefore be added to each of the average farm values of he two wheat and the two oat crops in the two corn rotations (1 and 4), and their um should be divided by two in order to make the net average farm value per acre of the two corn rotations comparable to that of the two summer-tilled rotations (5 and 8). The same end is accomplished by adding one-half the average farm value of the two corn crops to the average farm value of the two wheat and two oat crops in the corn rotations, as is done in the table.

The results of these tests tend very strongly toward the concl that a corn crop is a better preparation for spring wheat or oats th summer tillage under a wide range of soil and climatic conditions i the Great Plains.

TABLE XXIV.—*Disked corn stubble compared with summer tillage as a preparation f crops of wheat and oats.*

Station.	Year.	Average value per acre of wheat and oats.						Gain in favor of summer tillage.[a]	[illegible]
		Rotation No. 1.	Rotation No. 4.	Rotations Nos. 1 and 4.	Rotation No. 5.	Rotation No. 8.	Rotations Nos. 5 and 8.		
Judith Basin, Mont	1909	$20.66	$21.11	$20.89	$21.47	$22.02	$21.75	$0.86	......
Dickinson, N. Dak	1908	16.03	15.72	15.87	15.81	15.29	15.55	......	[illegible]
Do	1909	21.60	21.17	21.39	20.88	21.70	21.29	......	[illegible]
Edgeley, N. Dak	1907	8.90	7.47	8.18	7.66	7.19	7.42	......	[illegible]
Do	1908	11.14	8.22	9.68	10.86	6.22	8.54	......	[illegible]
Do	1909	19.50	18.10	18.80	18.50	16.41	17.46	......	[illegible]
Highmore, S. Dak	1906	14.81	16.74	15.77	16.50	20.01	18.26	2.49	......
Do	1907	13.48	15.96	14.72	18.24	18.48	18.36	3.64	......
Do	1908	11.61	11.88	11.75	12.87	15.24	14.05	2.30	......
Bellefourche, S. Dak	1909	17.16	20.16	18.66	17.16	22.74	19.95	1.29	......
North Platte, Nebr	1907	10.73	13.35	12.04	12.48	14.63	13.55	1.51	......
Do	1908	17.62	17.54	17.58	20.87	23.11	21.99	4.41	......
Do	1909	9.98	8.41	9.19	11.02	5.04	8.03	......	[illegible]
Akron, Colo	1909	11.34	6.38	8.86	7.96	7.52	7.74	......	[illegible]
Hays, Kans	1908	5.39	4.41	4.90	4.65	5.58	5.12	.22	......
Garden City, Kans	1909	.75	.70	.73	2.48	2.01	2.24	1.51	......
Dalhart, Tex	1909	......	......	......	2.31	1.50	1.91	1.91	......
Amarillo, Tex	1908	6.71	7.38	7.04	8.61	9.12	8.86	1.82	......
Do	1909	1.50	......	.75	5.14	3.84	4.49	3.74	......
Average	......	11.52	11.30	11.41	12.39	12.51	12.45	1.04	......

Station.	Year.	Returns from corn crop.			Net gai per acre rotations and 4 i favor of disked corn stubble.
		Fodder.	Grain.	Total.	
Judith Basin, Mont	1909	$11.47	......	$11.47	[illegible]
Dickinson, N. Dak	1908	3.13	......	3.13	[illegible]
Do	1909	2.97	$18.84	21.81	[illegible]
Edgeley, N. Dak	1907	4.33	......	4.33	[illegible]
Do	1908	3.48	......	3.48	[illegible]
Do	1909	4.38	11.82	16.20	[illegible]
Highmore, S. Dak	1906	......	14.95	14.95	[illegible]
Do	1907	......	9.13	9.13	[illegible]
Do	1908	......	8.36	8.36	[illegible]
Bellefourche, S. Dak	1909	5.26	7.69	12.95	[illegible]
North Platte, Nebr	1907	7.01	7.23	14.24	[illegible]
Do	1908	5.11	10.27	15.38	[illegible]
Do	1909	3.78	10.19	13.97	[illegible]
Akron, Colo	1909	4.03	9.73	13.76	[illegible]
Hays, Kans	1908	7.86	5.27	13.13	[illegible]
Garden City, Kans	1909	3.97	......	3.97	[illegible]
Dalhart, Tex	1909	1.31	......	1.31	[illegible]
Amarillo, Tex	1908	4.57	6.37	10.94	[illegible]
Do	1909	2.13	......	2.13	[illegible]
Total	......	74.79	119.85	194.64	......
Average	......	......	......	10.24	[illegible]

[a] Corn not considered.

NG CORN STUBBLE GIVES BETTER RESULTS THAN PLOWING FOR SPRING WHEAT WHICH IS TO FOLLOW.

Table XXV a comparison has been made between the average
values of rotations Nos. 1 and 3. These two rotations are
ical, except that in No. 1 the corn stubble was disked and in No.3
s fall plowed. In eleven tests, the disking, and in seven tests,
plowing, gave best results. The average was 36 cents per acre
vor of disking. In none of the tests was the gain in favor of
ing sufficient to more than pay for the extra labor, and in four
as insignificant. On the other hand, the gain from disking was,
re tests, enough, together with the less cost of disking, to make the
ing decidedly the better practice. It may therefore be con-
red that these investigations indicate that disking is the better
tice at all the stations.

TABLE XXV.—*Disking compared with plowing corn stubble for spring wheat.*

Station.	Year.	Average value per acre of wheat and oats.		Gain in favor of disking.	Gain in favor of plowing.
		Rotation No. 1, disked.	Rotation No. 3, plowed.		
th Basin, Mont.	1909	$20.66	$18.53	$2.13	....
inson, N. Dak.	1908	16.03	16.33	....	$0.30
Do.	1909	21.60	20.57	1.03	....
ley, N. Dak.	1907	8.90	8.35	.55	....
Do.	1908	11.14	8.78	2.36	....
Do.	1909	19.50	19.72	....	.22
nmore, S. Dak.	1906	14.81	14.73	.08	....
Do.	1907	13.48	14.96	....	1.48
Do.	1908	11.61	12.16	....	.55
efourche, S. Dak.	1909	17.16	17.01	.15	....
th Platte, Nebr.	1907	10.73	10.80	....	.07
Do.	1908	17.62	17.36	.26	....
Do.	1909	9.98	10.04	....	.06
n, Colo.	1909	11.34	8.58	2.76	....
s, Kans.	1908	5.39	4.19	1.20	....
den City, Kans.	1909	.75	.66	.09	....
hart, Tex.	1908	....	....	....	....
arillo, Tex.	1908	6.71	6.67	.04	....
Do.	1909	1.50	2.67	....	1.17
Average.		11.52	11.16	.36	....

THE RELATIVE MERITS OF FALL AND SPRING PLOWING DEPEND UPO LOCAL CONDITIONS OF SOIL AND CLIMATE.

In Tables XXVI and XXVII comparisons have been made betwe fall-plowed and spring-plowed rotations. In Table XXVI four fa plowed and three spring-plowed rotations have been used, while i Table XXVII only two rotations have been used. The results of t two tables do not agree. The first table is probably the less tru worthy of the two, as it introduces several other factors, whi undoubtedly obscure the results of the time of plowing. The t rotations presented in Table XXVII are strictly comparable, as th differ only in this one factor. Neither of these tables gives resu that are at all decisive. The only conclusions that can be dra are: That the natural character of the soil, its physical condition the time of plowing, the holding of snow by stubble during t winter, the liability to blowing during the winter, and the kind crop to be grown must all be considered. It would seem from the results that, until further evidence is secured, the farmer should his plowing at the time that the soil is in best condition for plowi and when he can use his teams and men to the best advantage. T depth of plowing and the amount of harrowing after plowing mu also be determined by local and seasonal conditions.

TABLE XXVI.—*Spring plowing compared with fall plowing.*

Station.	Year.	Fall-plowed rotations.					Spring-plowed rotations.				Difference in favor of fall
		Average value per acre of wheat and oats. No. 1.	Average value per acre of wheat and oats. No. 3.	Average value per acre of wheat and oats. No. 4.	Average value per acre of oats and barley. No. 6.	Average value per acre, fall-plowed rotations.	Average value per acre of wheat and oats. No. 2.	Average value per acre of barley and oats. No. 7.	Average value per acre of wheat and oats. No. 9.	Average value per acre, spring-plowed rotations.	
Judith Basin, Mont.	1909	$20.66	$18.53	$21.11	$16.79	$19.27	$19.40	$18.53	$20.08	$19.34	
Dickinson, N. Dak.	1908	16.03	16.33	15.72	15.37	15.86	18.37	15.67	13.20	15.75	
Do.	1909	21.60	20.57	21.17	19.50	20.71	21.00	19.89	19.90	20.26	
Edgeley, N. Dak.	1907	8.90	8.35	7.47	8.35	8.27	8.42	5.74	2.10	5.42	
Do.	1908	11.14	8.78	8.22	8.45	9.15	7.83	8.65	6.59	7.69	
Do.	1909	19.50	19.72	18.10	15.33	18.16	19.33	15.35	16.54	17.07	
Highmore, S. Dak.	1906	14.81	14.73	16.74	15.24	15.38	14.01	14.17	16.25	14.81	
Do.	1907	13.48	14.96	15.96	12.16	14.14	14.94	11.95	14.48	13.79	
Do.	1908	11.61	12.16	11.88	11.14	11.70	13.10	11.68	13.50	12.76	
Bellefourche, S. Dak.	1909	17.16	17.01	20.16	18.79	18.28	13.55	14.16	17.16	14.96	
North Platte, Nebr.	1907	10.73	10.80	13.35	9.28	11.04	11.96	12.99	11.25	12.07	
Do.	1908	17.62	17.36	17.54	12.09	16.10	12.73	13.28	12.48	12.83	
Do.	1909	9.98	10.04	8.41	7.04	8.87	9.37	8.77	9.13	9.09	
Akron, Colo.	1909	11.34	8.58	6.38	7.85	8.54	8.99	8.06	6.92	7.99	
Hays, Kans.	1908	5.39	4.19	4.41	7.66	5.41	4.35	1.65	3.52	3.17	
Garden City, Kans.	1909	.75	.66	.70	1.44	.89	1.39	4.03	1.10	2.17	
Dalhart, Tex.	1909	......	......	......	......	......	......	......	......	......	
Amarillo, Tex.	1908	6.71	6.67	7.38	6.12	4.72	5.91	4.73	4.96	5.20	
Do.	1909	1.50	2.67	......	......	1.04	......	......	......	......	
Average.	......	11.52	11.16	11.30	10.14	......	10.77	9.97	9.43	......	

TABLE XXVII.—*Spring plowing compared with fall plowing.*

Station.	Year.	Average value per acre of wheat and oats.		Gain in favor of—	
		Rotation No. 2.	Rotation No. 3.	Spring plowing.	Fall plowing.
Basin, Mont	1909	$19.40	$18.53	$0.87	
on, N. Dak	1908	18.37	16.33	2.04	
	1909	21.00	20.57	.43	
y, N. Dak	1907	8.42	8.35	.07	
	1908	7.83	8.78		$0.95
	1909	19.33	19.72		.39
ore, S. Dak	1906	14.01	14.73		.72
	1907	14.94	14.96		.02
	1908	13.10	12.16	.94	
urche, S. Dak	1909	13.55	17.01		3.46
Platte, Nebr	1907	11.96	10.80	1.16	
	1908	12.73	17.36		4.63
	1909	9.37	10.04		.67
Colo	1909	8.99	8.58	.41	
Kans	1908	4.35	4.19	.16	
City, Kans	1909	1.39	.66	.73	
t, Tex	1909	.00	.00	.00	
llo, Tex	1908	5.91	6.67		.76
	1909	.00	2.67		2.67
Average		10.77	11.16		.39

RELATION OF WHEAT AND OATS TO SUMMER TILLAGE IN A THREE-YEAR ROTATION.

he comparison in Table XXVIII of rotation No. 5, where wheat,
No. 8, where oats, follow summer tillage gives some interesting
rmation. At Judith Basin, Mont., where only one year's results
e been secured, the advantage was slightly in favor of oats fol-
ing summer tillage. At Dickinson, N. Dak., the difference was
only small but also contradictory for the two years. At Edge-
, N. Dak., the advantage was in favor of No. 5, wheat after fallow
three years. At Highmore, S. Dak., the advantage was with
. 8, oats after fallow all three years. At Bellefourche, S. Dak.,
single year's results are markedly in favor of No. 8. At North
tte, Nebr., the advantage was with No. 8 in 1907 and 1908 and
h No. 5 in 1909. For reasons already explained, the last year's
ults at this station were reversed by unfavorable weather condi-
ns in May. The results indicate that No. 8 is the better for North
atte. The results of the tests at the other stations were indecisive.
appears, therefore, that at Edgeley the advantage is decidedly in
vor of No. 5, wheat after summer tillage. At Highmore, Belle-
urche, and North Platte the advantage is as strongly in favor of
o. 8, oats after summer tillage. The other stations show no marked
lvantage in favor of either rotation over the other.

TABLE XXVIII.—*Fallow, wheat, oats (rotation No. 5) compared with fallow,* *wheat (rotation No. 8).*

Station.	Year.	Average value per acre of—		Gain in favor of—	
		Wheat and oats. Rotation No. 5.	Oats and wheat. Rotation No. 8.	Rotation No. 5.	
Judith Basin, Mont	1909	$21.47	$22.02		
Dickinson, N. Dak	1908	15.81	15.29	$0.52	
Do	1909	20.88	21.70		
Edgeley, N. Dak	1907	7.66	7.19	.47	
Do	1908	10.86	6.22	4.64	
Do	1909	18.50	16.41	2.09	
Highmore, S. Dak	1906	16.50	20.01		
Do	1907	18.24	18.48		
Do	1908	12.87	15.24		
Bellefourche, S. Dak	1909	17.16	22.74		
North Platte, Nebr	1907	12.48	14.63		
Do	1908	20.87	23.11		
Do	1909	11.02	5.04	5.98	
Akron, Colo	1909	7.96	7.52	.44	
Hays, Kans	1908	4.65	5.58		
Garden City, Kans	1909	2.48	2.01	.47	
Dalhart, Tex	1909	2.31	1.50	.81	
Amarillo, Tex	1908	8.61	9.12		
Do	1909	5.14	3.84	1.30	
Average		12.39	12.51		

WHEAT, OATS, CORN A BETTER SEQUENCE ON SPRING PLOWING TH OATS, WHEAT, CORN AT MOST STATIONS.

In Table XXIX a comparison of rotations Nos. 2 and 9 shows th when spring plowing is practiced the wheat-oats-corn sequence giv better results than the oats-wheat-corn sequence, Highmore and Bell fourche, S. Dak., and Judith Basin, Mont., being the only statio where the latter sequence gives better results than the former.

In Table XXX the same comparisons have been made betwe rotations Nos. 1 and 4. In these rotations the corn stubble w disked instead of plowed and the two other plats in each of th rotations were fall plowed instead of being spring plowed, as we rotations Nos. 2 and 9.

The results of this comparison agree in a general way with thos of rotations Nos. 2 and 9, but are less markedly in favor of the corn wheat-oats sequence, the net gain of this sequence being only 2 cents instead of 82 cents per acre. The four tests giving results i favor of the corn-oats-wheat sequence in Table XXIX also gav like results in Table XXX. There are, however, three addition tests in the latter comparison in favor of the corn-oats-wheat sequenc i. e., Highmore, 1907, North Platte, 1907, and Amarillo, 1908.

E XXIX.—*Comparison of rotations Nos. 2 and 9 in detail, showing the effect of sequence, in dollars and cents per acre.*

Station.	Year.	Value of wheat per acre.		Value of oats per acre.		Average value per acre.	
		Rotation No. 2.	Rotation No. 9.	Rotation No. 2.	Rotation No. 9.	Rotation No. 2.	Rotation No. 9.
h Basin, Mont	1909	$19.86	$18.96	$18.93	$21.21	$19.40	$20.08
nson, N. Dak	1908	21.00	11.22	15.75	15.18	18.37	13.20
o	1909	23.82	18.42	18.18	21.39	21.00	19.90
ley, N. Dak	1907	7.92	2.52	8.91	1.68	8.42	2.10
o	1908	9.48	8.10	6.18	5.07	7.83	6.59
o	1909	19.56	15.48	19.11	17.61	19.33	16.54
more, S. Dak	1906	16.38	15.42	11.64	17.07	14.01	16.25
o	1907	17.40	14.70	12.48	14.25	14.94	14.48
o	1908	15.12	14.52	11.07	12.48	13.10	13.50
fourche, S. Dak	1909	14.34	15.66	12.75	18.66	13.55	17.16
h Platte, Nebr	1907	14.22	12.48	9.69	10.02	11.96	11.25
Do	1908	14.40	10.50	11.07	14.46	12.73	12.48
Do	1909	10.32	10.00	8.43	8.25	9.37	9.13
n, Colo	1909	12.48	8.58	5.49	5.25	8.99	6.92
s, Kans	1908	.90	1.32	7.80	5.73	4.35	3.52
len City, Kans	1909	2.40	1.50	.39	.69	1.39	1.10
art, Tex	1909	.00	.00	.00	.00	.00	.00
rillo, Tex	1908	4.80	3.18	7.02	6.75	5.91	4.96
Do	1909	.00	.00	.00	.00	.00	.00
Average		11.81	9.61	9.73	10.30	10.77	9.95

Station.	Year.	Gain in value per acre of wheat.		Gain in value per acre of oats.		Gain in value per acre.	
		Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.	Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.	Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.
dith Basin, Mont	1909	$0.90			$2.28		$0.68
kinson, N. Dak	1908	9.78		$0.57		$5.17	
Do	1909	5.40			3.21	1.10	
geley, N. Dak	1907	5.40		7.23		6.32	
Do	1908	1.38		1.11		1.24	
Do	1909	4.08		1.50		2.79	
ghmore, S. Dak	1906	.96			5.43		2.24
Do	1907	2.70			1.77	.46	
Do	1908	.60			1.41		.40
ellefourche, S. Dak	1909		$1.32		5.91		3.61
orth Platte, Nebr	1907	1.74			.33	.71	
Do	1908	3.90			3.39	.25	
Do	1909	.32		.18		.24	
kron, Colo	1909	3.90		.24		2.07	
ays, Kans	1908		.42	2.07		.83	
arden City, Kans	1909	.90			.30	.29	
alhart, Tex	1909	.00	.00				
marillo, Tex	1908	1.62		.27		.95	
Do	1909	.00	.00				
Average		2.20			.57	.82	

TABLE XXX.—*Comparison of rotations Nos. 1 and 4 in detail, showing the effect of sequence, in dollars and cents per acre.*

Station.	Year.	Value of wheat per acre.	Value of oats per acre.		Value of wheat per acre.	Average value per acre.	
		Rotation No. 1.	Rotation No. 1.	Rotation No. 4.	Rotation No. 4.	Rotation No. 1.	Rotation No. 4.
Judith Basin, Mont.	1909	$20.88	$20.43	$22.23	$19.98	$20.66	$21.11
Dickinson, N. Dak.	1908	21.48	10.59	20.16	11.28	16.03	15.72
Do.	1909	23.88	19.32	21.75	20.58	21.60	21.17
Edgeley, N. Dak.	1907	10.02	7.77	8.64	6.30	8.90	7.47
Do.	1908	14.40	7.89	7.02	9.42	11.14	8.22
Do.	1909	19.80	19.20	19.11	17.10	19.50	18.10
Highmore, S. Dak.	1906	16.02	13.59	18.48	15.00	14.81	16.74
Do.	1907	12.90	14.07	14.52	17.40	13.48	15.96
Do.	1908	14.58	8.64	10.68	13.08	11.61	11.88
Bellefourche, S. Dak.	1909	17.64	16.68	22.50	17.82	17.16	20.16
North Platte, Nebr.	1907	13.38	8.07	12.18	14.52	10.73	13.35
Do.	1908	17.16	18.09	16.29	18.78	17.62	17.54
Do.	1909	13.02	6.93	6.75	10.08	9.98	8.41
Akron, Colo.	1909	15.00	7.68	6.39	6.36	11.34	6.38
Hays, Kans.	1908	2.22	8.55	4.80	4.02	5.39	4.41
Garden City, Kans.	1909	.60	.90	.87	.54	.75	.70
Dalhart, Tex.	1909	.00	.00	.00	.00	.00	.00
Amarillo, Tex.	1908	4.98	8.43	6.84	7.92	6.71	7.38
Do.	1909	.00	3.00	.00	.00	1.50	.00
Average.	....	12.52	10.52	11.54	11.06	11.52	11.30

Station.	Year.	Gain in value of wheat.		Gain in value of oats.		Gain in value per acre.	
		Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.	Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.	Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.
Judith Basin, Mont.	1909	$0.90	....	....	$1.80	....	$0.45
Dickinson, N. Dak.	1908	10.20	....	....	9.57	$0.31	....
Do.	1909	3.30	....	....	2.43	.43	....
Edgeley, N. Dak.	1907	3.72	....	....	.87	1.43	....
Do.	1908	4.98	....	$0.87	....	2.92	....
Do.	1909	2.70	....	.09	....	1.40	....
Highmore, S. Dak.	1906	1.02	....	....	4.89	....	1.93
Do.	1907	....	$4.50	....	.45	....	2.48
Do.	1908	1.50	....	....	2.04	....	.27
Bellefourche, S. Dak.	1909	....	.18	....	5.82	....	3.00
North Platte, Nebr.	1907	....	1.14	....	4.11	....	2.62
Do.	1908	....	1.62	1.80	....	.08	....
Do.	1909	2.94	....	.18	....	1.57	....
Akron, Colo.	1909	8.64	....	1.29	....	4.96	....
Hays, Kans.	1908	....	1.80	3.75	....	.98	....
Garden City, Kans.	1909	.06	....	.03	....	.05	....
Dalhart, Tex.	1909	.00	.00	.00	....	....	....
Amarillo, Tex.	1908	....	2.94	1.59	....	....	.67
Do.	1909	.00	....	3.00	....	1.50	....
Average.	....	1.46	....	....	1.02	.22	....

ROTATIONS FOR THE CONSERVATION OF ORGANIC MATTER IN THE SOIL.

The conservation of the organic matter in the soil is probably the most important problem in crop rotation. In the various 3-year rotations which have been discussed in the foregoing pages no attention has been paid to this important subject for the reasons already given, that its introduction in these experiments would tend to obscure the effects of sequence and methods of soil preparation. A great deal of work has, however, been done at these same stations with various rotations calculated to conserve the organic matter in the soil. There are several reasons why the results from these experiments have not yet reached the stage where any very safe conclusion can be drawn. Among the most important of these reasons are the following:

(1) Rotations planned for this purpose must be of at least four and, preferably, six years' duration; and a complete cycle of the rotation should be completed before results will be at all marked.

(2) The plowing under of sod or green manure is frequently less beneficial to the crops immediately following than to the subsequent crops. Under certain conditions of soil and climate the first effect may be even to reduce rather than to increase the following crop. This is especially true where a green-manure crop is allowed to become too mature before plowing under, where a grass or clover sod is broken when it is not in the best condition for plowing, or where the soil is not properly treated after plowing.

(3) The great diversity of soil and climatic conditions encountered at the several stations has made it impossible always to foresee just how the best results can be obtained. Some experiments and some mistakes had to be made before the best methods of investigation could be worked out.

(4) The growing of most of the cultivated perennial grasses, the biennial and annual legumes, and the winter grains is still in the early experimental stages at many of the stations. The failure to secure a catch of seed and the injury or total loss of the crop by winterkilling has in some instances seriously interfered with carrying out the plans of the experiments.

(5) Experience is enabling us to gradually reduce these sources of error, but they can never be entirely eliminated. It will therefore require a much longer period of time to reach the same degree of accuracy in these investigations as that attained with the simple 3-year rotations and the continuous cropping and summer tillage experiments already described.

(6) Another important consideration in this connection is that the effects of all these methods are cumulative. Continuous cropping or

alternate cropping and summer tillage without the application of barnyard or green manure must in time deplete the soil of its organic matter and consequently reduce both its drought resistance and its fertility. On the contrary, a properly planned and conducted rotation system should maintain or augment the store of organic matter in the soil and thereby increase both its fertility and its drought resistance, and consequently its crop-producing capacity. Such being the case it would be manifestly unreasonable to expect to establish any definite quantitative relations between two such diverging systems until after a lapse of sufficient time to allow the rate of this divergence to become definitely established.

While the results of these investigations have not yet reached the stage where definite quantitative relations can be established, they have, we believe, produced sufficient evidence to warrant us in making certain recommendations and suggestions for rotations in the Great Plains.

In the following pages we have attempted to outline certain systems of crop rotation which will combine the best features of the extensive system of farming with the conservation of the organic matter, as well as the moisture of the soil. These rotations, as well as many others, have been on trial at nearly all the stations mentioned and have given sufficiently favorable results to warrant their recommendation for further trials by farmers in the Great Plains area.

The following tables are intended to represent a quarter section of land divided into as many fields as there are years in the rotation. Of course, this would apply equally as well to a farm of more or less extent than 160 acres, but as a quarter section is the common unit of land measurement in the West we have assumed that each of these rotations is to be practiced upon a single quarter. The letters assigned to the plats indicate the crops to be raised on each plat for as many years as are involved in the particular rotation under consideration. When this cycle has been completed it will be begun over and the same crops will be raised in the same succession continuously as long as the rotation is practiced.

It is quite important in planning a rotation to devote a great deal of careful thought and attention to the matter, as the best results will obtain where the rotations are carried on uninterruptedly for long periods. It is true that many minor changes may be made in the rotation without seriously interfering with its general plan. We have attempted to point out some of the ways in which the following rotations may be modified to suit local conditions.

Where annual crops only are used, the beginning of the rotation is a very simple matter. All that is necessary is to divide the farm into as many fields of uniform size as there are years in the rotation and en seed each field to the crops in the rotation in regular order, as is own in the tables.

Where biennial or perennial crops enter into the rotation, as is the se with rotations Nos. 1 and 2, it will be necessary the first year to pply some other crop in the place of the perennial, which, when the tation is once started, will be carried on from the previous year. or instance, in the case of the 6-year rotation (No. 2) the farm hould be divided into six fields of equal area, as shown. Field A hould be planted to corn, field B to wheat, and field C should be eeded to brome-grass. Field D should also be seeded to brome-rass, as it will remain as a meadow during the following year. ield E, which should be in brome-grass, but would be broken up after he grass was cut, should be planted to some other crop. It is not mportant what this crop should be, except that if the rotation has een adopted with a view to furnishing the proper quantity of hay it ould be desirable to have this field put into some kind of an annual rop that could be cut for hay. Millet, oats and peas sown together, milo, or some of the other nonsaccharine sorghums, could be used for this purpose. Field F would be sown to oats, barley, emmer, or wheat, as shown. After the first year the rotation would go on without further interruption, except that in the case of a failure of the grass to catch, some annual could be substituted without in any way interfering with the general plan of the rotation.

FIVE-YEAR ROTATION (NO. 1).

FIELD A, 32 ACRES.

1910.	Corn.
1911.	Wheat, winter or spring.
1912.	Brome-grass meadow.
1913.	Brome-grass meadow.
1914.	Oats, barley, emmer, or wheat.

FIELD B, 32 ACRES.

1910.	Wheat, winter or spring.
1911.	Brome-grass meadow.
1912.	Brome-grass meadow.
1913.	Oats, barley, emmer, or wheat.
1914.	Corn.

FIELD C, 32 ACRES.

1910.	Brome-grass meadow.
1911.	Brome-grass meadow.
1912.	Oats, barley, emmer, or wheat.
1913.	Corn.
1914.	Wheat, winter or spring.

FIELD D, 32 ACRES.

1910.	Brome-grass meadow.
1911.	Oats, barley, emmer, or wheat.
1912.	Corn.
1913.	Wheat, winter or spring.
1914.	Brome-grass meadow.

FIELD E, 32 ACRES.

1910.	Oats, barley, emmer, or wheat.
1911.	Corn.
1912.	Wheat, winter or spring.
1913.	Brome-grass meadow.
1914.	Brome-grass meadow

This rotation is one that has proved very satisfactory in our experiments, and it is believed that with the modifications that may be made in it, it will be found adapted to a large portion of the Great Plains area. It is possible that the order in which the crops are grown might be changed, but from our experience in this particular we have found this arrangement the most satisfactory. This being a 5-year rotation, the farm would be divided into five fields of 32 acres each. There would be 32 acres of corn, 64 acres of small grain, and 64 acres of meadow each year.

Corn.—This crop may be grown either upon fall plowing or spring plowing. The time of planting must be determined by the experience of farmers in the particular locality where it is to be tried. It is believed that, as a broad general proposition, spring plowing gives better results than fall plowing, but there are some notable exceptions to this general rule. If the ground is to be plowed in the fall, the plowing should be done as soon after the preceding crop is harvested as possible. The depth to which the plowing should be done is a matter that depends largely upon local conditions of soil and climate, and also upon the depth to which plowing has been done in previous years. It is not usually desirable to plow more than about 1 inch of soil that has not been previously stirred.

In the northern part of the area it will be impracticable to attempt any cultivation of the ground during the winter when the soil is frozen, but in the southern portion of the area, where the ground is not constantly frozen and where there is more or less winter rain, it would probably be advisable to harrow the ground after rains in order to preserve the moisture. In the spring the land may be disked or harrowed after rains to conserve the moisture until planting time. Where the soil is of such a nature as to cause it to blow badly, the fall, winter, and spring treatment should be such as to reduce this danger to the lowest point. No general rule can be laid down which would be applicable to the many different soils to be found in the area. The planting may be done with a checkrower or with a lister; whichever method is used the ground should be frequently cultivated after planting with a weeder or light harrow, or with some of the implements used for cultivated and listed ground. When the grain has reached the height where this class of implements can not be used, it should be thoroughly cultivated, not only to keep it free from weeds, but to keep the crust broken, so as to conserve the moisture. In cultivating the corn crop, two objects should constantly be kept in view: (1) The cultivation of the soil with reference to the corn crop, and (2) the preparation of the soil for the grain crop which is to follow. Experience has shown that where corn does not grow oftener than once in three years in the rotation it does not pay to plow the land after the corn crop and before the succeeding crop is sown. If a crop of winter wheat is to be raised, the wheat should either be drilled in between the rows of standing corn, as is found desirable in the northern part of the area, or the corn should be cut and either shocked or removed from the field and the grain sown on disked corn stubble.

Wheat.—If spring wheat is to be raised after the crop of corn, it will often be found advantageous to disk or harrow the corn stubble in the fall, after the corn is removed, in order to break up the crust and conserve the moisture resulting from the fall rains when they occur. In the spring the grain can be drilled in upon the corn stubble with either a disk or a shoe drill. If the cornstalks were not removed the previous fall, but were left standing, it will be necessary to break them down with some kind of a stalk cutter, such as is in common use wherever corn is extensively raised. In some instances it may be found necessary to disk the land before drilling in the wheat, but the soil is of such a nature over very considerable areas as to make this unnecessary and in some instances actually undesirable. A light harrowing after seeding is almost unfailingly beneficial, as it helps to cover the seed that may not have been completely covered by the drill, and also levels the surface. Light harrowing after the grain has come up and until it has reached a height where the harrowing will seriously harm the plants is usually desirable. On some soils this work can be better done with some one of the various types of weeders that are on the market. This harrowing of the grain after it is up should be done as soon after rains as the soil is dry enough, so as not to clog the harrow or weeder.

If brome-grass is to be sown with the wheat, the seeding of wheat should be as light as is consistent with a fair yield of grain. It would be impossible to lay down any rule as to the quantity per acre, but we have found 3 pecks per acre satisfactory. The brome-grass seed should be sown at the rate of about 20 pounds of good clean seed per acre. The seed may be sown either with the grass-seed attachment to the drill or broadcast by hand, and should be covered by a light harrowing. Where a man can be found who is accustomed to sowing seed by hand we have found the hand seeding the most satisfactory, as there is great danger of the brome-grass seed becoming clogged in the seeder on account of its light and chaffy nature.

Where winter wheat is raised, the brome-grass may usually be sown in the fall at the time of the seeding of wheat. If a good catch of brome-grass is not obtained from this fall seeding, it is possible to reseed the thin patches in the spring, covering the ground with a light harrow or weeder.

Brome-grass meadow.—If a good catch of brome-grass has been obtained, there should be a good yield of both hay and seed the following year. Where brome-grass seed is in demand, the seed crop is usually much more profitable than the hay crop, but, of course, only a small portion of the total crop of brome-grass can be used for this purpose each year in a locality where it is being extensively grown. The second year's crop of brome-grass usually yields more hay but less seed per acre, so that as a general thing the seed should be saved from the first year's crop and the second year's crop used mainly for hay. We have sometimes found it desirable to cut the seed with a binder, setting it high enough so as not to cut the thick mass of grass at the bottom, and to follow the binder with a mowing machine to cut the hay. In cutting brome-grass for seed great care should be exercised to harvest it at just the right time; that is, as soon as the seed is mature and before it begins to shed. We have frequently seen a crop of seed reduced one-half by a delay of two days in cutting.

After the second year's crop of brome-grass has been cut the sod should be broken in order to prepare the land for the crop of oats, barley, emmer, or wheat which is to follow. The proper time for breaking the sod will depend upon the locality, soil, and climatic conditions. In the northern part of the area it will be found entirely practicable to cut a crop of hay in June, break the sod immediately, and sow a crop of flax upon the sod. In this way two crops can be obtained from the field the same year, and, in addition to the advantage of raising two crops, the soil will be in better condition for the crop of grain which is to follow the next year than it would be if the sod was simply broken and allowed to remain without a crop until the following spring.

Oats, barley, emmer, or wheat.—The treatment of the brome-grass sod from the time it is broken until the seeding of the following spring is a matter concerning which it is very difficult to lay down any very definite rule. The object is, of course, to get the sod as thoroughly rotted and subdued as possible and to get the soil into the best possible condition for the seed bed for the spring crop. The means adopted to attain this end will depend so much upon local conditions, peculiarities of soil, climate, etc., that the farmer will have to depend largely upon his own judgment and experience. If a crop of flax has been raised, the sod will rot much more rapidly than where flax is not raised, and it will usually be found desirable to backset the sod in the fall if there is sufficient moisture in the soil. Where a crop of flax has not been raised, the question of backsetting in the fall or allowing the sod to remain undisturbed until the following spring is one that must depend upon local conditions.

SIX-YEAR ROTATION (NO. 2)

Field A, 26⅔ Acres.

). Corn.
1. Wheat, winter or spring.
2. Seeded to brome-grass.
3. Brome-grass meadow.
4. Brome-grass meadow.
5. Oats, barley, emmer, or wheat.

Field B, 26⅔ Acres.

10. Wheat, winter or spring.
11. Seeded to brome-grass.
12. Brome-grass meadow.
13. Brome-grass meadow.
14. Oats, barley, emmer, or wheat.
15. Corn.

Field C, 26⅔ Acres.

10. Seeded to brome-grass.
11. Brome-grass meadow.
12. Brome-grass meadow.
13. Oats, barley, emmer, or wheat.
14. Corn.
15. Wheat, winter or spring.

Field D, 26⅔ Acres.

1910. Brome-grass meadow.
1911. Brome-grass meadow.
1912. Oats, barley, emmer, or wheat.
1913. Corn.
1914. Wheat, winter or spring.
1915. Seeded to brome-grass.

Field E, 26⅔ Acres.

1910. Brome-grass meadow.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.
1914. Seeded to brome-grass.
1915. Brome-grass meadow.

Field F, 26⅔ Acres.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Seeded to brome-grass.
1914. Brome-grass meadow.
1915. Brome-grass meadow.

In some of the drier parts of the Great Plains area it will probably e found impracticable to attempt to raise brome-grass with a nurse rop. In such localities rotation No. 1, as previously described, hould be modified by making it a 6-year instead of a 5-year rotaion. With the 6-year rotation the farm would be divided into six ields of 26⅔ acres each, and we would, therefore, have 26⅔ acres of orn, 53⅓ acres of brome-grass, 53⅓ acres of small grain, and 26⅔ acres sown to brome-grass, but not yielding a crop. All the crops in the rotation would follow each other in the order already specified, except that there would be one year between the wheat crop and the first year of brome-grass meadow, during which the seeding of brome-grass would be done.

When this modification of the rotation is adopted, the following method will be found satisfactory for preparing the land for seeding to brome-grass. The land should be plowed as soon after the crop of wheat has been removed as is practicable. The treatment of the soil after plowing should be such as will carry it through the winter in the best physical condition. As soon as the frost is out of the surface the following spring it should be harrowed, and this harrowing should continue until the ground becomes thoroughly warm and that time of the season has been reached when there is most likelihood of rains. In the Dakotas this time is usually the first week in

June. In other parts of the area it may vary somewhat, but when the time arrives and the soil is thoroughly warm and in good condition and when there is a reasonable prospect of rain the brome-grass should be sown, as heretofore described, at the rate of about 20 pounds per acre and thoroughly harrowed in. The weeds having been kept down by previous harrowings and the soil having become packed into a firm seed bed and being moist and warm, the brome-grass should come up very quickly and evenly and will be able to keep ahead of the weeds, and a good stand ought to be the result in almost any part of the area during years of normal climatic conditions.

FOUR-YEAR ROTATION (NO. 3).

Field A, 40 Acres.

1910. Corn.
1911. Wheat, winter or spring.
1912. Red clover.
1913. Oats, barley, emmer, or wheat.

Field B, 40 Acres.

1910. Wheat, winter or spring.
1911. Red clover.
1912. Oats, barley, emmer, or wheat.
1913. Corn.

Field C, 40 Acres.

1910. Red clover.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

Field D, 40 Acres.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Red clover.

In some parts of the area clover has been successfully grown, and it is believed that it might be very much more extensively grown than it is at present. As it is a nitrogen gatherer, it is more desirable for improving the condition of the soil than is brome-grass, and we would therefore recommend the modification of rotation No. 2 by making it a 4-year rotation, which would necessitate the dividing of the farm into four fields of 40 acres each, as shown in rotation No. 3. There would then be 40 acres in corn, 80 acres in small grain, and 40 acres in clover each year. The clover can be sown with the wheat at the rate of about 15 pounds per acre. If it proves impracticable to raise clover with the wheat as a nurse crop, the rotation can be changed to a 5-year rotation, seeding the clover on thoroughly prepared ground, as discussed for brome-grass in the 6-year rotation (No. 2). Flax might be raised on the clover sod, as suggested for brome-grass sod.

FOUR-YEAR ROTATION (NO. 4).

FIELD A, 40 ACRES.

10. Corn.
11. Wheat, winter or spring.
12. Winter rye turned under in spring.
13. Oats, barley, emmer, or wheat.

FIELD B, 40 ACRES.

10. Wheat, winter or spring.
11. Winter rye turned under in spring.
12. Oats, barley, emmer, or wheat.
13. Corn.

FIELD C, 40 ACRES.

1910. Winter rye turned under in spring.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

FIELD D, 40 ACRES.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Winter rye turned under in spring.

While we feel confident that brome-grass and red clover can be uch more commonly grown throughout this area than at present, e recognize that there probably are localities within the area here neither of these crops can be successfully grown, and it is ltogether likely that even in those localities where the crops can be uccessfully grown during favorable seasons there will be unfavorble seasons when it will be impossible to get a catch of either of hem. In order to provide for such emergencies we have included he following 4-year rotation, No. 4, in which we have substituted a rop of winter rye for the clover which occurred in rotation No. 3. he other crops in this rotation will not need further description, as hey are to be treated the same as in the rotations described.

The ground for the winter rye should be prepared by plowing it as oon after the wheat crop is removed as possible. It should then e thoroughly packed and harrowed and kept in good tilth and free rom weeds until the proper time for seeding has arrived. The date f seeding, of course, will vary somewhat with the latitude. After he rye is seeded it will require no further attention until the following pring or early summer, when it is to be turned under. The date when this should be done will, of course, vary with the season, but xperience has shown that the best results are obtained when the rye is turned under after it has attained nearly its full growth but while it is still young and succulent and has not become hard and woody. This stage will vary somewhat in the same locality on account of the difference in weather conditions from season to season, so that each farmer must use his own judgment in determining whether the grain has reached the proper stage for plowing under. As soon as it is plowed under, the ground should be thoroughly packed and harrowed in order to prevent the rye straw from drying out in the soil instead of rotting. After the rye has been turned under, the field should be treated like summer tillage for the remainder of the season until the following spring, provided a spring crop is to be sown. If the field is to be sown to winter grain in the fall, the treatment should be the same as the summer tillage up to the time of seeding.

If this rotation is adopted and the plowing under of the winter rye is carefully done and the after-culture is sufficiently thorough, much better results will undoubtedly be obtained than from the summer tillage without the growing of a crop for turning under. The great objection to summer tillage is the fact that it is very destructive to the organic matter or humus in the soil, while this rotation will preserve and even increase the organic matter in the soil. The cost of seeding the field to rye is not great, and the labor involved is no more than would be necessary for the summer tillage carried on as thoroughly as it should be.

FOUR-YEAR ROTATION (NO. 5).

Field A, 40 Acres.

1910. Corn.
1911. Wheat, winter or spring.
1912. Field peas or cowpeas turned under in spring.
1913. Oats, barley, emmer, or wheat.

Field B, 40 Acres.

1910. Wheat, winter or spring.
1911. Field peas or cowpeas turned under in spring.
1912. Oats, barley, emmer, or wheat.
1913. Corn.

Field C, 40 Acres.

1910. Field peas or cowpeas turned under in spring.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

Field D, 40 Acres.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Field peas or cowpeas turned under in spring.

Rotation No. 5 is exactly like rotation No. 4 except that field peas or cowpeas will be used in the place of the winter rye. As both of these crops have the power of gathering the free nitrogen from the air and converting it into forms in which it can be used by succeeding crops, they are preferable in this respect to winter rye. The preparation of the land during the fall after the wheat has been removed should be the same as that recommended for fall plowing for other crops. In the spring the field peas or cowpeas should be sown as early as climatic conditions will permit. The time of seeding will, of course, depend upon the locality, and the rate of seeding should depend upon the fertility of the soil. As heavy a seeding should be given as the soil is capable of developing, as it is desirable, of course, to get as large an amount of growth for turning under as possible. Some very favorable results have been obtained by substituting sweet clover (*Melilotus alba*) for peas. When this is done, the sweet clover should be sown with the wheat crop and plowed under the next season before any seeds have matured, as it becomes a very bad weed in some localities.

What has already been said concerning the stage of growth of the e and also concerning the treatment of the field after plowing under e crop will apply equally well to either field peas, cowpeas, or sweet ver.

THE PRINCIPLES OF CROP ROTATION.

FACTORS INVOLVED.

Crop rotation, with its concomitant features of farm organization, versification of crops, and stock raising, is destined to become the ost important problem in the agricultural development of the Great ains. It is therefore worthy of the most careful study by all who e interested directly or indirectly in this development. It is one of e most complex and difficult of agricultural problems. The prin- pal difficulties arise from the fact that the planning of a rotation a long-time proposition, the laying out of plans reaching many ars into the future, which makes it necessary to deal with factors hich are constantly changing, both absolutely and relatively. Some these changing factors are: The constantly varying absolute and lative prices of all the crops grown, of the live stock to which some these crops must be fed, and of the products of this live stock; vari- le weather conditions; the attacks of diseases and insect enemies, here the same crop is grown too frequently on the same land; the arying cost of labor; the uncertainty and, in some instances, the tter impracticability of raising perennial crops for meadow or pas- re; and many others which will readily occur to the thoughtful udent of the problem.

In no field of scientific investigation or of the practical application f scientific principles is dogmatism more utterly out of place than the study or practice of crop rotation. The factors of the prob- em are so local and individual in their nature, so closely associated ith the local characteristics of each farm and its environment and he individual tastes, abilities, and limitations of each farmer, that o definite and specific directions can be given for establishing a otation for any farm until all the factors are carefully studied. here are, however, certain general principles which are fairly well stablished. There are others which are strongly indicated by the nvestigations which have been described, but which may be either irmly established or disproved by a continuation of these investigations. Among the established principles may be mentioned the ollowing:

(1) All crops may be roughly classified under three heads: Exhaus- ive, intermediate, and restorative. These terms must not be taken oo literally. All crops which are harvested and removed from the land take from it more or less plant food and might therefore be said to be "exhaustive." No crop "restores" to the soil any considera-

ble amount of plant food unless it is plowed under for green manure or is allowed to decay upon the surface. But, nevertheless, certain crops leave the land in poorer condition for a subsequent crop of some particular kind than it was before they were raised. These are designated as "exhaustive" crops, and include wheat, oats, barley, rye, and millet. Their ill effects upon subsequent crops may be due to a reduction of the available plant food; to an increased growth of weeds, fungi, or injurious insects; to a change in the physical condition of the soil, particularly its water content; or to a reduction in the quantity or activity of beneficial lower organisms. "Restorative" crops have the opposite effect. They leave the soil in better condition for certain crops than it was before. Among restorative crops may be mentioned corn, potatoes, beans, peas, clover, alfalfa, most cultivated crops grown in the Great Plains, and perennial grasses grown for meadow or pasture. "Intermediate" crops are those that have, in some respects, a beneficial effect upon certain crops which follow them, while in other respects their influence is detrimental. The sorghums, cane, milo, and kafir belong to this class. Their beneficial effects are due to the fact that, like all cultivated crops, they reduce the amount of weeds in subsequent crops; their detrimental effects upon subsequent crops seem to be due to the fact that they are able to exhaust the soil moisture to a greater extent than any other crops commonly grown in the Great Plains.

(2) In addition to and in a certain measure independent of the above-mentioned classification is the problem of crop sequence, or the relations which two crops bear to each other independent of any apparent difference in the conditions of the soil brought about by their growth. For instance, two crops may be equally exhaustive, but when grown consecutively, better results will be obtained if they are grown in one sequence than when the opposite sequence is followed. Oats following wheat generally give better results than wheat following oats. Or, again, a restorative crop may have a more beneficial effect upon some certain exhaustive crop which follows it than it has upon some other equally exhaustive crop. Wheat generally responds more readily to the effects of a corn crop than does oats.

(3) The effects of the preparation of the land—time and depth of plowing, disking instead of plowing, the amount of harrowing and packing of the seed bed, etc.—depend not only upon the crop for which preparation is being made, but also upon the crop grown the preceding year and the previous soil treatment.

(4) The selection of the varieties or strains of the crops grown which are best adapted to the particular locality and to the rotation planned and the determination of the quantity of seed to use and of the method and time of seeding are also of great importance.

5) The keeping of as much live stock of the most profitable kind
l the feeding out upon the farm and the returning of the manure
he land of as large a proportion of the crops raised as is consistent
h immediate profits is also of great importance.

n planning a rotation a recognition of the above-mentioned
nciples will require that the following rules be observed:

RULES TO BE OBSERVED IN PLANNING ROTATIONS.

1) Select as large a number of restorative and as small a number
exhaustive crops as is consistent with the general plan of farm
anization.

2) Arrange the crops in the rotation so as to have the exhaustive
d restorative crops alternate as far as possible.

(3) Observe the proper sequence, both between restorative and
haustive crops and between two exhaustive crops where it becomes
cessary to grow two such crops consecutively.

(4) Select the best varieties or strains and use the quantity of seed
d the method and time of seeding best adapted to the locality.

(5) Plow and prepare the seed bed at the time and in the manner
st adapted to the crop, the soil, the climate, and the most econom-
al distribution of labor through the year.

(6) Obtain all available information concerning yields, cost, and
ices of crops grown in the locality, and plan to grow those crops that
ill yield the largest net return per acre with the least depletion of
il fertility.

(7) Feed as large a proportion as possible of the crops grown and
turn the manure to the field.

(8) Raise the kind of live stock yielding the largest net profit and
est adapted to the particular farm and locality and to the preferences
f the farmer who handles it. Very few farmers ever make a success
f raising any kind of live stock the care of which they do not enjoy.

(9) Use perennial grasses, alfalfa, or clover in the rotation wherever
racticable, and where it is impracticable to do so raise rye, peas, or
weet clover for green manuring to maintain the humus in the soil.

It is believed that the tentative conclusions drawn from the results
f the investigations described in this bulletin will materially aid in
he establishment of rotations which will meet the above-mentioned
equirements.

CONCLUSIONS FROM EXPERIMENTS.

(1) The practice of summer tillage and alternate cropping has not given results to warrant its recommendation as a safe basis for a permanent agriculture in the Great Plains area, where spring-grown wheat, oats, and barley are the staple crops. It may, however, be resorted to as a safeguard or temporary expedient to guard against

the total loss of the crop where extreme drought is anticipated, but it can not be depended upon to produce as profitable crops under average normal conditions as may be produced by other methods. (See Tables I, II, III, XXI, and XXIII.)

(2) Continuous cropping with moisture-conservation methods, involving early fall plowing and thorough fall, winter, and spring tillage and harrowing after the grain is up in the spring, has not given average results to warrant its practice. There have, however, been a few exceptions to this rule. (See Tables I, II, III, XXI, and XXIII.)

(3) A simple 3-year rotation of corn, wheat, and oats has given more profitable returns than any method of continuous cropping or alternate cropping and summer tillage in fourteen out of seventeen tests. In the three instances where continuous cropping gave better returns the difference was so small as to be practically negligible. (See Table XXIII and the preceding tables, of which it is a summary.)

(4) The two 3-year rotations giving the best average results are No. 1 (wheat on disked corn ground, oats on fall plowing, corn on fall plowing) and No. 6 (barley on disked corn ground, oats on fall plowing, corn on fall plowing). These two rotations are identical except that barley has been substituted for wheat in No. 6. One or the other of these two rotations gave the best results at nine of the eighteen tests: Dickinson, N. Dak., 1909, Edgeley, N. Dak., 1907 and 1908, Highmore, S. Dak., 1907, Bellefourche, S. Dak., 1909, North Platte, Nebr., 1908, Akron, Colo., 1909, Hays, Kans., 1908, and Amarillo, Tex., 1908. (See Table XXIII.)

(5) Rotation No. 7, oats, barley, corn, all on spring-plowed land, gave the best results at three tests: Highmore, S. Dak., 1908, North Platte, Nebr., 1909, and Garden City, Kans., 1909. (See Table XXIII.)

(6) Rotation No. 3 (wheat, oats, corn, all on fall plowing) and rotation No. 4 (oats on disked corn ground, wheat on fall plowing, corn on fall plowing) each gave the best results at two tests: Edgeley, N. Dak., 1909, and Amarillo, Tex., 1909, for No. 3; Judith Basin, Mont., 1909, and North Platte, Nebr., 1907, for No. 4. (See Table XXIII.)

(7) Rotation No. 2 (wheat, oats, corn, all on spring plowing) gave the best results at only one test, Dickinson, N. Dak., 1908. (See Table XXIII.)

(8) Rotation No. 9 (oats, wheat, corn, all on spring plowing) failed to give the best results at any test and averaged 42 cents per acre poorer than continuous cropping. (See Table XXIII.)

(9) Summer tillage had been introduced in rotations Nos. 5 and 8 in place of corn. These two rotations are otherwise identical with rotations Nos. 1 and 4, respectively. A comparison of these two pairs

rotations shows that in seven out of nineteen tests the corn rotans (1 and 4) produced better crops of wheat and oats than the mmer-tilled rotations (5 and 8). In ten of the twelve tests where e yields of wheat and oats were better on summer-tilled rotations an on corn rotations the yield of corn was sufficient to more than fset this difference.

The two tests where the corn crop did not equal in value the gain om summer tillage were Dalhart and Amarillo, Tex. In these tests e crops of wheat and oats averaged only $1.91 and $4.49 per acre, espectively.

The average net gain of the corn rotations over the summer-tilled otations for all tests was $4.08 per acre and the results were in avor of the corn rotations in seventeen out of nineteen tests. (See able XXIV.)

(10) Disking has given better average results than plowing corn tubble as a preparation for wheat in eleven out of eighteen tests, he net results being 36 cents per acre in favor of disking. (See Table XXV.)

(11) Fall plowing has given slightly better net results than spring plowing. Local conditions of soil and climate influence the results so profoundly that no general conclusions can be drawn. The natural character of the soil, its physical condition at the time of plowing, its liability to blowing during the fall and winter, and the holding of snow by stubble during the winter must all be considered for each farm and each season in determining the best time of plowing. The most economical distribution of labor through the year is also an important practical consideration. (See Tables XXVI and XXVII.)

(12) When summer tillage is introduced in a rotation containing both wheat and oats, slightly better average results have been obtained when oats follow summer tillage and wheat follows oats than where wheat follows summer tillage and oats follow wheat. Local conditions of soil and climate influence results in this respect to such an extent that no general rule can be made to apply to all stations. Certain stations give markedly better results from one sequence, while others give much better results from the opposite sequence. (See Table XXVIII.)

(13) Where corn, wheat, and oats have been grown in a 3-year rotation, better results have been obtained in twenty-four out of thirty-five tests by following wheat after corn and corn after oats. At Judith Basin, Mont., Highmore and Bellefourche, S. Dak., North Platte, Nebr., and Amarillo, Tex., better results have been obtained from the opposite sequence. The greatest advantage of the corn-wheat-oats sequence was at Edgeley, N. Dak., in 1907, when it

amounted to $6.32 per acre. This was closely followed by North Platte, Nebr., in 1909, and Dickinson, N. Dak., in 1908, where it amounted to $5.24 and $5.17, respectively. Highmore and Bellefourche, S. Dak., are the only stations showing markedly better results from the corn-oats-wheat sequence. The effects of the sequence seem to be less marked where the corn stubble is disked and the other plats fall plowed than where all plats are spring plowed. (See Tables XXIX and XXX.)

(14) Wherever a perennial meadow grass, like brome-grass (*Bromus inermis*), can be profitably grown it should enter into the rotation, which should be not less than five years in duration. The following has given good results: Corn; wheat, winter or spring; brome-grass, two or three years; oats, barley, emmer, or wheat (winter or spring).

Flax may be sown on the brome-grass sod as a catch crop after the hay crop has been harvested. Where this practice is adopted it will of course be impracticable to follow the flax with fall-sown grain, but spring-sown grain can be substituted.

(15) Where it is impracticable to secure a catch of brome-grass or other meadow grass sown with the wheat crop, the grass should be sown separately on carefully prepared ground in May or June. This will require a rotation of at least six years' duration. There will be one year (the year of seeding to grass) during which one field will yield no crop return, but if flax is grown on the meadow sod after the hay has been cut two crops will be obtained from this field in one year. In this way as many crops will be grown as there are fields in the rotation system.

(16) Wherever alfalfa can be profitably grown it may be substituted in whole or in part for the brome-grass without interfering with the general plan of the rotation.

(17) Wherever clover can be profitably grown it can be sown with the brome-grass without changing the general plan of the rotation: or it can be sown separately, either with the wheat in a 4-year rotation or without a nurse crop in a 5-year rotation.

(18) Where neither perennial grasses nor perennial legumes or clovers can be profitably raised, rye, peas, or sweet clover should be raised every fourth year and plowed under for green manure. Rye has so far given better average results than peas, sweet clover, or summer tillage. This seeming superiority may be due to the fact that the quantity of organic matter is greater in the rye and that it can be turned under earlier in the season, thus allowing the rains of June and July to be conserved in the soil instead of being consumed in the growth of the green-manure crop. It seems quite probable that the greater quantity of nitrogen gathered and restored to the

il by the legumes will in time overcome the advantage which the e now seems to have.

(19) Wherever winter wheat can be safely grown it should con-itute a considerable portion of the small-grain crop. The danger om winterkilling tends to make it a more precarious crop than ring-sown grains. On the other hand, its earlier maturity, which equently allows it to escape the droughts of early summer, and its gher yield when conditions are favorable give it a marked advan-ge over spring wheat. It should be raised in rotation with other ops.

When so raised, summer tillage will not usually be necessary or dvisable. Under certain circumstances it may be found desirable summer till, as winter wheat certainly responds much more readily summer tillage than do spring-sown crops. Summer tillage even r winter wheat can not be recommended as a general or frequent ractice in the Great Plains area. It is believed that the plowing nder of a green-manure crop early in the season and proper treat-ent of the soil from that time until seeded to winter grain will sually give as good immediate results as summer tillage. There an be little doubt as to the advantage of green manuring over sum-er tillage in its ultimate effect upon the soil.

The conclusions concerning summer tillage reached from our ivestigations throughout the Great Plains area are in general ccord with those of Mr. W. P. Snyder, superintendent of the Nebraska gricultural Experiment Substation, at North Platte, Nebr., and f Mr. W. W. Burr, assistant in dry-land agriculture, detailed to hat substation from the Bureau of Plant Industry. We therefore uote from an article prepared by them and published in Bulletin o. 109 of the Agricultural Experiment Station of Nebraska, as ollows:

> *Ultimate effect of summer tilling.*—Frequent summer tilling may be more or less detrimental to our land. The changes which break down the humus in the soil go on ery rapidly under the conditions afforded by summer tilling and must exhaust the ntire supply more quickly than where some method is practiced which does not urnish so good conditions for the destruction of humus in the soil.
>
> We feel safe in recommending summer tillage for small grain, especially winter wheat, but advise that a rotation be followed which will keep up the organic matter in the soil and conserve its fertility. Such a rotation will probably use summer tillage n the same field only once during a series of years, and will have a grass, legume, or ome green manuring crop which will put back into the soil the organic material taken from it. Where sufficient barnyard manure is to be had, an application of it once during the rotation will probably keep up the humus and conserve the fertility of the soil. Where manure is used it should be applied as evenly as possible on the land, and disked to mix it with the surface. It should be applied at a time and in such a manner as to be a benefit rather than a harm to the succeeding crop.
>
> From our experience we can not lay down a definite system of rotation for all conditions. The rotations must be worked out to suit the farm where they are to be

practiced. A rotation that seems well adapted to our conditions is as follows: Summer tillage, winter wheat, corn, spring grain, cane. Summer till and sow winter wheat; disk and fall plow the wheat stubble for corn the next year; disk the corn stubble for a spring grain—oats, wheat, or barley; apply manure during the winter, disk in spring and plow for cane, which crop completes the rotation. To practice this rotation a farm should have at least five fields. This 5-year rotation gives winter wheat on summer-tilled land to be sold as a cash crop, corn and spring grain to be fed or sold according to conditions, and cane for forage. If the forage and grains are fed, there will be enough manure to apply in the rotation, covering one-fifth of the land each year.

In exclusive grain farming, which is a hazardous proposition at best, some crop must be turned under to keep up the fertility. This is equally true whether summer tilling be practiced or not. We have this year obtained very good results from green manuring with rye and with cowpeas. The yield was not up to that on summer-tilled land, but was nearly as large. In each case the crop was turned under and the land kept well tilled for the balance of the summer, and the land sown to grain in the spring. If this can be done with a reasonable certainty of success, it may be more profitable than summer tilling. It gives much the same condition of the land as summer tillage and at the same time enriches the soil by the addition of humus. In very dry years it is doubtful if this will give as high yields as summer tilling, since there will be hardly enough water to rot the crop turned under and give a good seed bed in which to sow the next crop.

We feel that the practice of summer tilling is and can be kept profitable by systematic rotation of crops in which summer tilling shall be used only occasionally. If used without care it may prove very detrimental. If used judiciously it will tend to free the fields from weeds and guard against total crop failure and to greatly extend the winter wheat growing area.

PRECIPITATION RECORDS.

Table XXXI presents the precipitation records by months for all stations reported upon in this bulletin, not only for the year during which the tests were conducted, but also for the year immediately preceding. A study of this table will give a general idea of the climatic conditions prevailing at each station for each year of the tests. It also furnishes some information concerning the quantity of water which may have been stored in the soil from the previous year. It should, however, be constantly borne in mind that the character of the rains and their distribution through the month greatly influence their availability to the crop. A large part of torrential rains may be lost by run-off. On the other hand, when the rains are less than one-half inch a day they may be almost entirely lost by evaporation. Again, there may be a heavy rainfall during the early part of the month, followed by a severe drought extending through the remainder of that month and the major part of the following month, with heavy precipitation during the later days. Under such circumstances the monthly precipitation for both months may seem to be ample, although crops may have suffered severely. This all goes to show that neither the annual nor the monthly precipitation as here given furnishes a safe basis for judging the weather onditions in their relation to crop production. These considera-ions apply more aptly to cases where the precipitation seems to be ufficient. If the monthly precipitation shows a marked deficit uring the growing season, it is reasonably safe to assume that the rop suffered from drought.

An examination of the accompanying table shows that when the hole record is considered there was an excess above normal pre-ipitation in 16 out of 30 instances and a deficit in 10 instances. here were 4 instances where the record was incomplete.

When we consider only the 19 cases where the observations were ade during the same year that these tests were made, we find that here was an excess in 11 instances, a deficit in 6, and incomplete ecords in 2.

Considering only the observations made at the 11 stations the year revious to the tests reported, we find that in 5 instances there was n excess, in 4 a deficit, and in 2 incomplete records.

It is apparent, therefore, that the average annual precipitation throughout the area was somewhat above normal, both during the years reported in these tests and for the year previous to the first reported tests. A detailed study of Table XXXI in connection with the yields reported in the respective tests may assist the reader in the interpretation of results. For a full discussion of these relations, however, it would be necessary to have the daily as well as the monthly precipitation, for the reasons already stated. These records are, of course, on file in the Office of Dry-Land Agriculture Investigations, but it has not seemed advisable to enter into a discussion of this phase of the subject in this bulletin. It may, however, be taken up in some future publication.

TABLE XXXI.—*Precipitation records for all dry-land agriculture stations in the Great Plains area, beginning one year prior to the years reported upon in this bulletin.*

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
Judith Basin, Mont.[a]	1908	0.55	0.49	0.98	0.61	7.31	2.45	0.20	1.18
Do	1909	.90	.08	1.22	.95	1.84	6.66	4.97	1.28
Dickinson, N. Dak	1907	.80	.14	.39	.30	1.36	2.52	4.82	1.89
Do	1908	.28	.73	1.42	1.27	3.50	4.30	1.41	1.41
Do	1909	.27	.52	.25	.51	5.78	3.28	1.89	5.54
Edgeley, N. Dak	1906	.13	T.	.16	1.58	5.59	3.69	3.17	1.56
Do	1907	.42	.06	.21	.35	1.89	1.73	2.77	1.21
Do	1908	.04	.65	1.45	1.26	3.53	3.26	1.19	1.69
Do	1909	.12	.25	T.	.70	4.01	2.80	3.04	1.73
Highmore, S. Dak	1905	.60	T.	.60	1.39	5.23	5.64	5.54	3.56
Do	1906	.30	.40	.80	2.30	5.00	2.50	1.19	6.74
Do	1907	1.00	.40	1.10	.68	5.11	1.62	3.64	.28
Do	1908	.10	.93	.80	1.55	2.68	5.78	2.49	3.53
Bellefourche, S. Dak.[b]	1908	(c)	(c)	(c)	[d] 1.09	4.09	1.47	1.26	.52
Do	1909	.17	.23	.19	.77	3.87	5.59	2.58	.55
North Platte, Nebr	1906	.61	.80	2.22	2.89	2.82	.68	3.14	5.56
Do	1907	.39	.51	.10	.43	2.40	2.69	6.79	2.14
Do	1908	.16	.78	.20	.64	3.95	5.07	3.17	1.57
Do	1909	.29	1.61	.98	.72	2.32	5.46	5.21	1.24
Akron, Colo	1908	.00	.34	T.	1.70	3.57	[b] 2.30	[b] 2.42	[b] 1.47
Do	1909	T.	1.38	3.06	[b] .40	[b] 1.76	[b] 3.43	[b] 4.61	[b] 3.77
Hays, Kans	1907	.64	.22	.85	.60	.83	4.97	9.15	3.12
Do	1908	T.	.92	T.	2.18	3.06	6.02	2.90	5.86
Garden City, Kans	1908	.08	.67	.18	.53	1.29	4.95	1.75	2.18
Do	1909	.30	.35	2.15	.20	3.06	3.48	5.22	.81
Dalhart, Tex	1908	T.	(c)	(c)	2.28	.53	2.83	3.89	1.05
Do	1909	T.	.28	.71	.17	1.64	5.10	1.27	.65
Amarillo, Tex	1907	1.11	.24	.02	1.25	.99	1.97	1.49	6.20
Do	1908	.26	.72	T.	1.90	3.55	1.73	5.40	2.75
Do	1909	.07	.28	1.28	.50	1.08	4.72	3.63	.87

Station.	Year.	Sept.	Oct.	Nov.	Dec.	Annual.	Average normal.	Above normal.	Below normal.
Judith Basin, Mont.[a]	1908	1.41	6.27	T.	0.22	21.67	15.25	6.42	....
Do	1909	4.27	.49	0.30	1.20	25.63	....	8.18	....
Dickinson, N. Dak	1907	1.11	.10	.02	.22	13.67	....	....	1.28
Do	1908	1.67	2.47	.78	.24	19.48	14.95	4.53	....
Do	1909	.83	1.08	.29	1.02	21.26	....	6.31	....
Edgeley, N. Dak	1906	1.45	.93	1.05	.65	19.96	....	.43	....
Do	1907	2.47	.41	T.	T.	11.52	....	....	8.01
Do	1908	1.81	1.34	.63	.20	17.05	19.53	....	2.48
Do	1909	.89	.42	.34	.84	15.14	....	....	4.39
Highmore, S. Dak	1905	.56	1.95	1.29	T.	26.36	....	10.42	....
Do	1906	2.81	2.41	.36	.40	25.21	....	8.45	....
Do	1907	1.04	1.96	.05	.40	17.28	....	....	.09
Do	1908	.62	2.19	1.39	.31	22.37	17.37	5.00	....
Bellefourche, S. Dak.[b]	1908	.52	1.08	.20	1.02	....	....	....	....
Do	1909	1.07	(c)	(c)	(c)	....	....	....	....
North Platte, Nebr	1906	4.25	3.05	1.01	.96	27.99	....	9.72	....
Do	1907	2.91	.14	.31	.80	19.61	....	1.02	....
Do	1908	.24	3.39	.59	.20	19.96	18.88	1.08	....
Do	1909	.77	.20	2.24	1.37	22.41	....	3.53	....
Akron, Colo	1908	[b] .05	3.20	2.00	T.	17.05	19.06	....	2.01
Do	1909	[b] 2.16	.76	.48	.55	22.36	19.06	3.30	....
Hays, Kans	1907	1.75	1.40	.11	1.76	25.40	....	2.86	....
Do	1908	.81	1.76	1.79	.03	25.33	23.48	1.85	....
Garden City, Kans	1908	1.04	1.07	2.72	.23	16.69	....	....	2.08
Do	1909	1.20	.75	3.77	.70	22.99	18.77	3.61	....
Dalhart, Tex	1908	.39	.29	.93	.06	....	....	....	....
Do	1909	2.12	2.60	1.21	.15	15.99	....	....	....
Amarillo, Tex	1907	.91	1.79	.66	1.46	18.09	....	....	4.46
Do	1908	1.83	.40	.51	.00	19.05	....	....	3.50
Do	1909	2.19	1.18	3.25	.54	19.59	22.55	....	2.96

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[a] Taken from Weather Report for Utica.
[b] From observations taken at the agricultural experiment stations and not from Weather Bureau reports.
[c] No report.
[d] No record by Weather Bureau observer
T.=trace.

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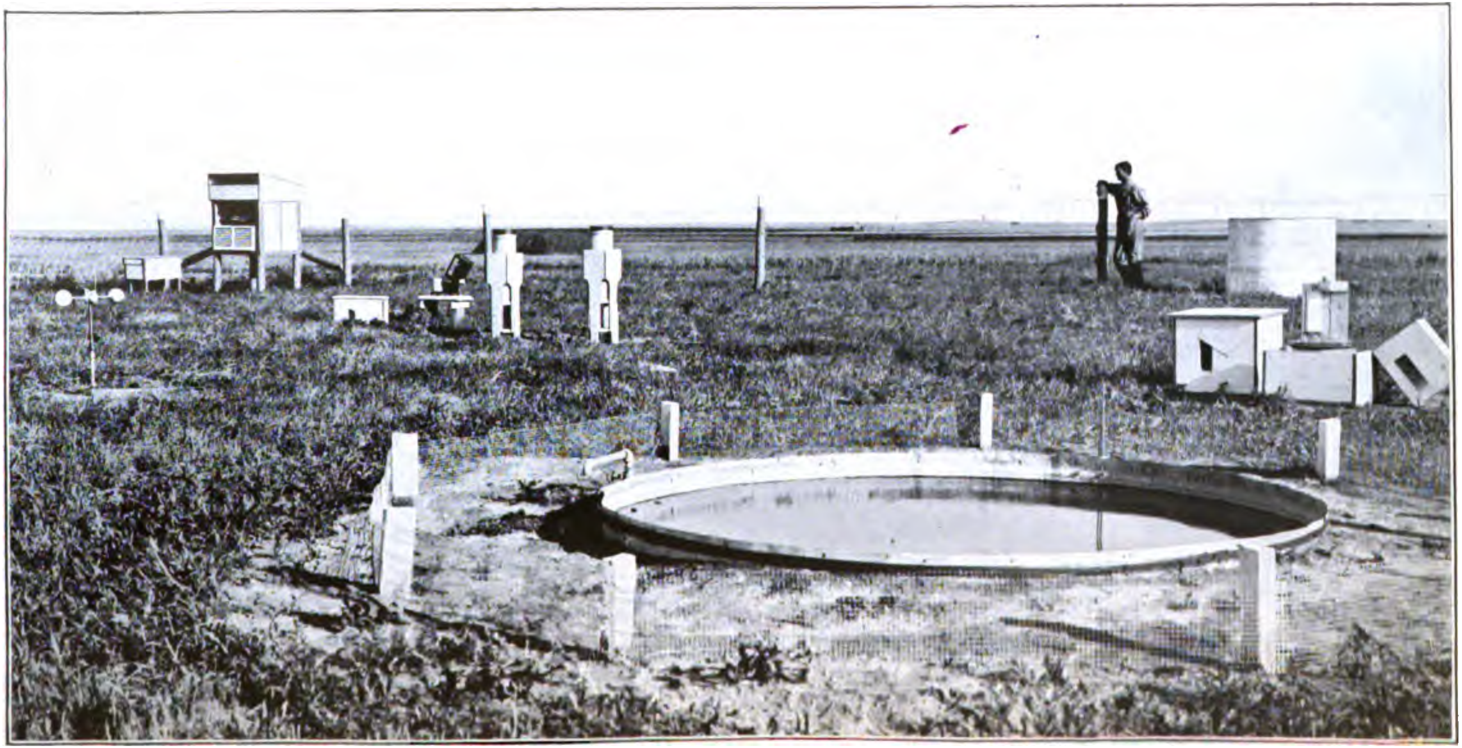

THE INSTRUMENT INCLOSURE AT THE HAYS EXPERIMENT FARM, HAYS, KANS.

The evaporation tank is shown in the foreground, with the recording evaporation gauge on the right. The rain gauge and hail gauge are shown in the center of the picture. The other instruments shown are for recording the temperature of the air and of the soil and the velocity of the wind.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 188.

B. T. GALLOWAY, *Chief of Bureau.*

DRY FARMING IN RELATION TO RAINFALL AND EVAPORATION.

NOV 18 1910

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RY FARMING IN RELATION TO RAINFALL AND EVAPORATION.

INTRODUCTION.

This bulletin contains a discussion of dry farming in relation to he amount and character of the rainfall and evaporation in the estern United States. Usually in discussing dry-farming conditions he annual precipitation is the only feature of the rainfall that receives ttention. But there are other factors in connection with the rainall that have much to do with the successful production of crops. he seasonal distribution of the rain, the rate at which the rain falls, nd the amount of rain that is lost through run-off from the surface ll have an important part in determining the percentage of the total ainfall that is really available for the use of crops. Finally, the mount of evaporation which takes place during the growing season etermines to some extent the amount of rain that is needed to produce a crop, and this varies greatly in different localities. Prospective settlers in these regions are apt to give very little attention to climatic features other than the total rainfall. They often do not even assure themselves that the figures given for a region represent the normal rainfall and not simply the rainfall for a single year. They ignore almost completely the seasonal distribution of the rain, the frequency of torrential rains, the loss of water through surface run-off, the occurrence of hail, and the amount of evaporation. It is the object of this paper to bring the importance of these factors to the attention of prospective settlers in regions of limited rainfall.

Tables are also appended showing the normal rainfall for practically every station in these regions where precipitation records are available. Accurate information regarding the precipitation in many sections of the West is now available as the result of the extended observations of the United States Weather Bureau. These records, which are often complete for many years and so become of great value to the prospective settler, have been used in computing the rainfall tables which are given in the concluding pages of this bulletin. The precipitation tables are also supplemented by state maps which show at a glance the distribution of the rainfall in the State. Lines showing points of equal annual rainfall have been drawn on these maps where sufficient observations were available. Maps of this kind have not before been available for these Western States.

CLASSIFICATION OF DRY-FARMING REGIONS.

Dry-farming regions are naturally classified on the basis of rainfall. In this country dry farming is usually considered to be confined to those regions in which the annual rainfall is less than 20 inches and more than 10 inches. This classification must be considered as only a rough approximation, since dry-farming districts can not be outlined on the basis of the annual rainfall alone on account of the great influence of the evaporation and the monthly distribution of the rain in growing dry-farm crops. Furthermore, it is impossible to say just where ordinary methods of farming leave off and dry-farming methods begin. Dry-farming methods are usually understood to mean those which lead to the conservation of moisture, but the conception of what these methods actually are varies greatly in different sections of the country. The dry farmer in the Great Plains, where the rainfall is from 15 to 20 inches, usually gets his best results with annual cropping methods combined with good tillage. On the other hand, the dry farmers in that part of the Great Basin where the rainfall is less than 15 inches follow the method of alternate cropping and summer tillage almost exclusively. Between these two classes there is a third operating under conditions where summer tillage may be necessary to insure returns on every crop, but where it frequently pays to take chances on producing a crop on the land each year.

The method of alternate cropping and summer tillage is generally recognized as the most highly developed dry-farming method because it gives better returns with a lower annual rainfall than other methods. There are considerable areas in central Utah that are cultivated in this way where the annual rainfall does not exceed 13 inches. It must be remembered, however, that this is a region of winter rainfall, and that the method of alternate cropping and summer tillage is particularly adapted for such regions, as we shall show later. Therefore, while the method of alternate cropping and summer fallowing is recognized as the most highly developed dry-farming method, it does not follow that it is the best method for all dry-farming regions or that it will always give the best returns. In dry-farming sections where the rainfall is not so limited as in Utah, and especially in regions having a summer rainfall, other methods give as good or better returns.

IMPORTANCE OF KNOWING THE NORMAL RAINFALL.

The rainfall in all parts of the United States is subject to wide fluctuations from year to year. The West does not appear to be more subject to these changes than the East, but the fluctuations are felt more by the dry farmers because they are working upon a closer margin. Crops in the East are often lost through drought and not infrequently under conditions where the up-to-date dry farmer would have produced a good crop. On account, then, of the fluctuations in rainfall in any locality from year to year, it is necessary in judging the rainfall of a region to know the average annual rainfall, or, as it is called, the normal rainfall. This is the only safe basis upon which the rainfall of any region can be judged, and the longer the records the greater is the dependence that can be placed upon the normal. While two years' or three years' observations are safer than a single year's records, it is not uncommon for two or three wet years or for two or three dry years to follow one another in succession, so that the yearly rainfall obtained at such times would be too high or too low. Records for at least five years, and preferably for ten years, are necessary to obtain the normal rainfall of a region, and the longer the records the more reliable will be the result obtained.

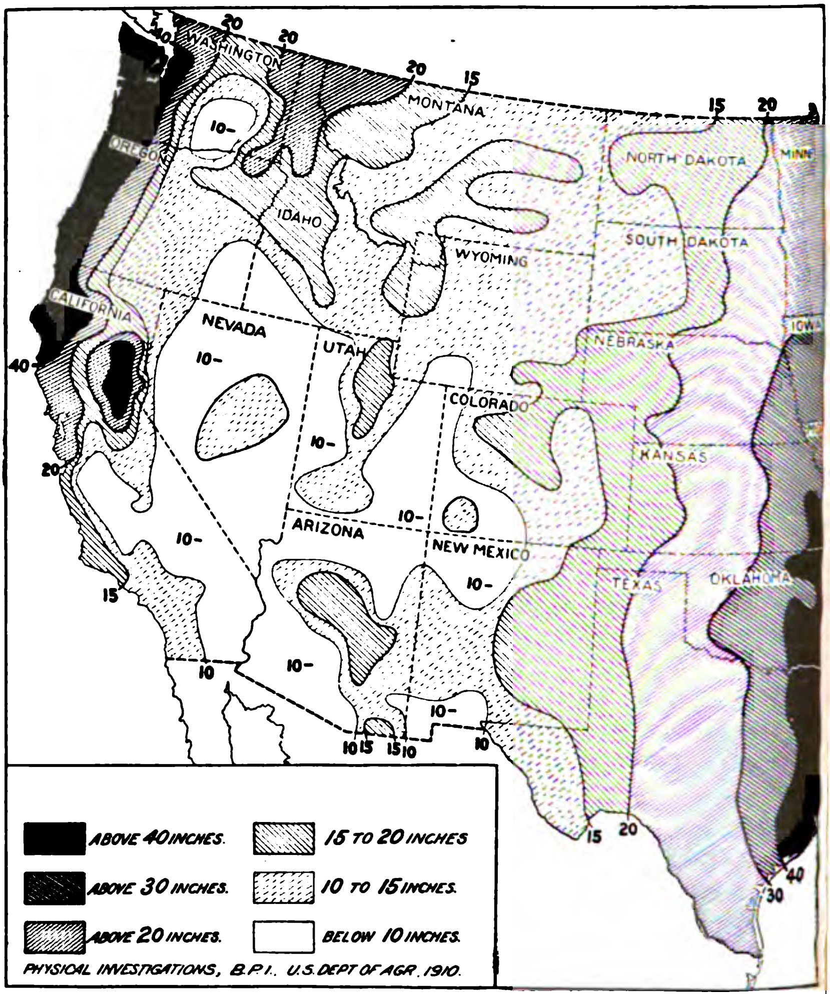
MANY RAINFALL STATIONS NECESSARY ON ACCOUNT OF LOCAL VARIATIONS IN RAINFALL.

In studying the rainfall of a region too much dependence must not be placed upon the records of a single station, especially if this station is located in a mountainous region. Under such conditions marked differences in the annual rainfall are often found between stations located on the highlands and those in the valleys. The cooling of the moisture-laden air through expansion as it rises over a range of hills causes precipitation, so that the windward sides of mountains have a greater rainfall than the leeward sides. This is well illustrated in the very heavy rains which occur all along the west slope of the Cascade Range in Washington, Oregon, and northern California, while the rainfall on the east side is very much less. (See the rainfall maps for Washington, fig. 22, and Oregon, fig. 17; also the chart shown as fig. 1.) This is also well illustrated in Riverside and San Bernardino counties in southern California (see map, fig. 7), where a great change in rainfall occurs as we go eastward a few miles.

These sudden changes in normal rainfall are not, however, confined to the mountainous regions; marked instances of this kind occur in the Great Plains, where changes in elevation are comparatively slight. For example, the rainfall in the district around Aberdeen, in Brown County, S. Dak., is nearly 5 inches above that of the surrounding sections. (See the South Dakota rainfall map, fig. 18.) This difference is based upon observations extending over twenty years or more; and the effect upon the crops has been so marked that the farmers generally recognize that good crops may be found in this section when the surrounding regions are suffering from drought. It is important, then, to have as many rainfall stations as possible in order to measure accurately the annual precipitation.

THE DISTRIBUTION OF THE ANNUAL RAINFALL IN DRY-FARMING REGIONS.

The accompanying chart (fig. 1) shows the annual rainfall in the western United States, and has been prepared by the writers with particular reference to dry-farming regions.[a] The region represented in the chart has been divided into zones, the boundaries of the zones being represented by lines along which the rainfall is uniform. For example, the heavy curved line marked 20, starting in the north-



PHYSICAL INVESTIGATIONS, B.P.I. U.S. DEPT OF AGR. 1910.

FIG. 1.—Chart showing the distribution of the annual rainfall in the dry-farming sections of the United States.

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[a] This chart is based upon the state rainfall maps (see pp. 33 to 45), which include the available rainfall records of the Weather Bureau to January, 1910.

stern corner of North Dakota and passing southward through ntral South Dakota, central Nebraska, western Kansas, and the anhandle of Texas, passes through points in these States where the rmal annual rainfall is 20 inches. The average annual rainfall of e country lying to the east of this line is in general more than 20 ches and to the west of this line less than 20 inches. This line, presenting points having a normal annual rainfall of 20 inches, is bout 4° of longitude, or approximately 200 miles, farther west Texas than in North Dakota.

The line representing an average annual rainfall of 15 inches ex- nds west in North Dakota nearly to the western boundary, then ends eastward and passes through the center of South Dakota, then ns westward through the southwestern corner of Wyoming, and aking a detour in the mountainous region of Colorado passes hrough the eastern part of that State and southward through the entral portion of New Mexico. The country lying between this ne of 15 inches annual rainfall and the line of 20 inches annual infall to the east has, then, an annual rainfall of 15 to 20 inches, e rainfall becoming greater as the 20-inch line is approached. A cond region in which the annual rainfall is between 15 inches and inches is shown in central Montana and northwestern Wyoming. third region having this rainfall is to be found in northwestern yoming and central Idaho and northeastern Oregon. Similar as exist in northern Utah, in the mountainous part of Arizona, d in northeastern California.

he line representing 10 inches of annual rainfall passes north west through the central part of California and through extreme tern Nevada, southeastern Oregon, and western Idaho, then ds sharply southward, making a great loop in the State of Utah, n runs through southwestern Wyoming, extreme western and thwestern Colorado, northwestern New Mexico, and northern d western Arizona. The unshaded area lying within this boundary as an annual rainfall of less than 10 inches. This area as a whole as not sufficient rainfall to make dry farming profitable, as it is arried on at the present time. The conditions are much more evere in the southern part of this area, owing to the higher evapora- ion. It is possible that grain may eventually be produced along he extreme northern border, particularly where other conditions are pecially favorable.

In southern Washington a second region is to be found in which he annual rainfall is less than 10 inches. The evaporation in this region is much lower than in the sections just mentioned. It has been found possible to produce wheat successfully within the borders of this region on an annual rainfall of about 9 inches, using the method of alternate cropping and summer tillage.

Those areas which are included between the 10-inch and 20-inch lines of annual rainfall serve, then, to represent in a general way the dry-farming areas of the United States so far as they may be defined through rainfall. It must be constantly borne in mind, however, that conditions are more severe in the southern part of the region than in the northern part, owing to the high temperature and greater evaporation; so that regions having the same rainfall are by no means equally well adapted to the production of crops.

COMPARISON OF THE MONTHLY DISTRIBUTION OF RAINFALL IN THE GREAT PLAINS, INTERMOUNTAIN, AND PACIFIC COAST REGIONS.

The monthly distribution of the rainfall in the western United States can be divided roughly into three types—the summer rainfall of the Great Plains, the winter and spring rainfall of the Intermountain district, and the winter rainfall of the Pacific coast region. These three types are illustrated in figure 2, which shows the monthly rainfall for three stations in each of these regions. It will be noted that for Bismarck, N. Dak., North Platte, Nebr., and Amarillo, Tex., which are typical Great Plains stations, the rain occurs principally during the months of June, July, and August, and that the winter

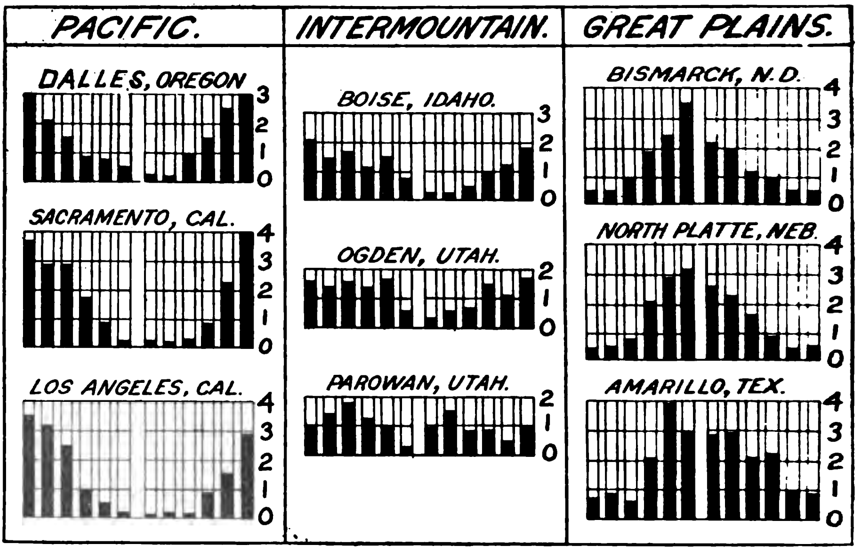

FIG. 2.—Chart showing the monthly distribution of the rainfall at representative stations in the Great Plains, Intermountain, and Pacific coast regions. The length of the black lines in each diagram represents the monthly precipitation at that place, beginning with January on the left. The scale in inches given on the right of each diagram can be used to find the actual amount of the monthly rainfall. For example, the average monthly rainfall at Bismarck, N. Dak., for June is seen to be 3½ inches, while for July it is only a little more than 2 inches. It will be noted that in the Pacific coast region the rain comes principally during the first and last months of the year, that is, in the winter, while in the Great Plains the rain comes principally during the middle of the year, that is, in the summer months.

months are very dry. In fact, about three-fourths of the total rainfall of the year at these stations occurs during the six summer months, from April to September, inclusive.

In the Pacific coast region, on the other hand, the rainfall occurs almost entirely during the winter months, and it will be seen from the chart that the summer months are very dry. The rainfall distribution in the Pacific coast region is, then, exactly opposite to that found in the Great Plains. In the Intermountain region the maximum precipitation occurs during the late winter and spring months. Thus there is here a distribution intermediate between that of the winter precipitation of the Pacific slope and the summer precipitation of the Great Plains.

The monthly distribution of the rainfall over the western portion of the United States is presented diagrammatically on the map shown as figure 1, which has been adapted from Bulletin N of the United States Weather Bureau. The change from a summer rainfall in the Great Plains to a winter rainfall on the Pacific coast is very marked, and the intermediate types are shown in the intervening country. In Arizona we find that the rainfall is divided into two periods during a year, a rainy season occurring during the winter months and a second rainy season in July and August, the latter being the greater.

THE RELATION OF MONTHLY DISTRIBUTION OF RAINFALL TO FARM PRACTICE.

In regions where the annual rainfall is low the monthly distribution of the rainfall determines to a large extent the farm practice of the region. A comparison of the systems of dry farming employed in the Great Basin and in the Great Plains will make this clear. In Utah and in a large part of the Great Basin country the precipitation comes largely in the winter and early spring. In consequence, spring wheat is not a successful crop in this region for two reasons: (1) The land can not be fitted for sowing until late in the season, owing to the spring rains, and (2) the driest part of the season occurs just when the spring-wheat crop would be maturing. On the other hand, the conditions in this region are almost ideal for growing winter wheat on summer-tilled land. The land is plowed in the fall so as to be left in the best condition for holding the snow and the winter and spring rains. It is then kept well tilled during the summer and contains sufficient moisture to start the crop in the fall. If a fall rain occurs about seeding time conditions are especially favorable. The fall-sown crop is then able to take advantage of the winter and spring precipitation and matures before the driest part of the season is reached. Clean summer fallowing (summer tillage) is considered absolutely necessary in this region in order to be sure of a successful crop on account of the low rainfall in the autumn months and for the purpose of supplementing the low annual rainfall.[a]

In the Great Plains the monthly distribution of the rainfall is quite different from that of the Intermountain region, the greatest monthly rainfall occurring in June, July, and August. Summer tillage for moisture conservation is not so well adapted to this region. The frequent rains during the summer months repeatedly pack the surface mulch on the summer-tilled land. This requires frequent cultivation in order to avoid the loss of water by evaporation, and so increases the expense of maintaining the mulch. Owing to the high evaporation in the Great Plains during the summer months, very little water will be stored in the summer-fallowed land unless the mulch is carefully kept up by thorough cultivation after every rain. The higher annual precipitation in the Great Plains and the increased cost of maintaining a good mulch on summer-tilled land have thus combined to make summer fallowing in this region much less popular than in the Great Basin country. Furthermore, the blowing of the dry surface mulch of the summer fallow sometimes becomes very serious in the Great Plains owing to high winds.

For the above reasons annual cropping is largely used in preference to summer tillage in the Great Plains, although in some parts of the area summer-tillage methods are considered necessary to insure sufficient moisture, even at the cost of the increased labor necessary to maintain the surface mulch. Spring grains are generally used under the annual cropping method, since the crop escapes the dry fall and winter, and the land, having been recently worked, is in the best condition to absorb the summer rainfall. The shade of the growing crop partially protects the ground from excessive loss of water by evaporation, while the small summer showers that are useless on summer-tilled land always help the growing crop. Thus we have a radically different system of farm practice in the Great Plains from that found in the Intermountain country, owing in part to the difference in the distribution of the monthly rainfall of the two regions and in part to the greater rainfall in the Great Plains.

THE RELATION OF THE CHARACTER OF RAINFALL TO ITS USEFULNESS.

The way in which the rain comes has a great deal to do with its usefulness. Summer-fallowing methods, for example, are not well adapted to regions in which the rainfall comes largely in the form of little showers from one-tenth to one-half inch. Rains of this kind penetrate the soil only a few inches, and the water is practically all

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[a] See "Arid Farming in Utah," by Widtsoe and Merrill, Bulletin 91, Utah Agricultural Experiment Station; also "Dry Farming in the Great Basin," by C. S. Scofield, Bulletin 103, Bureau of Plant Industry, U. S. Department of Agriculture.

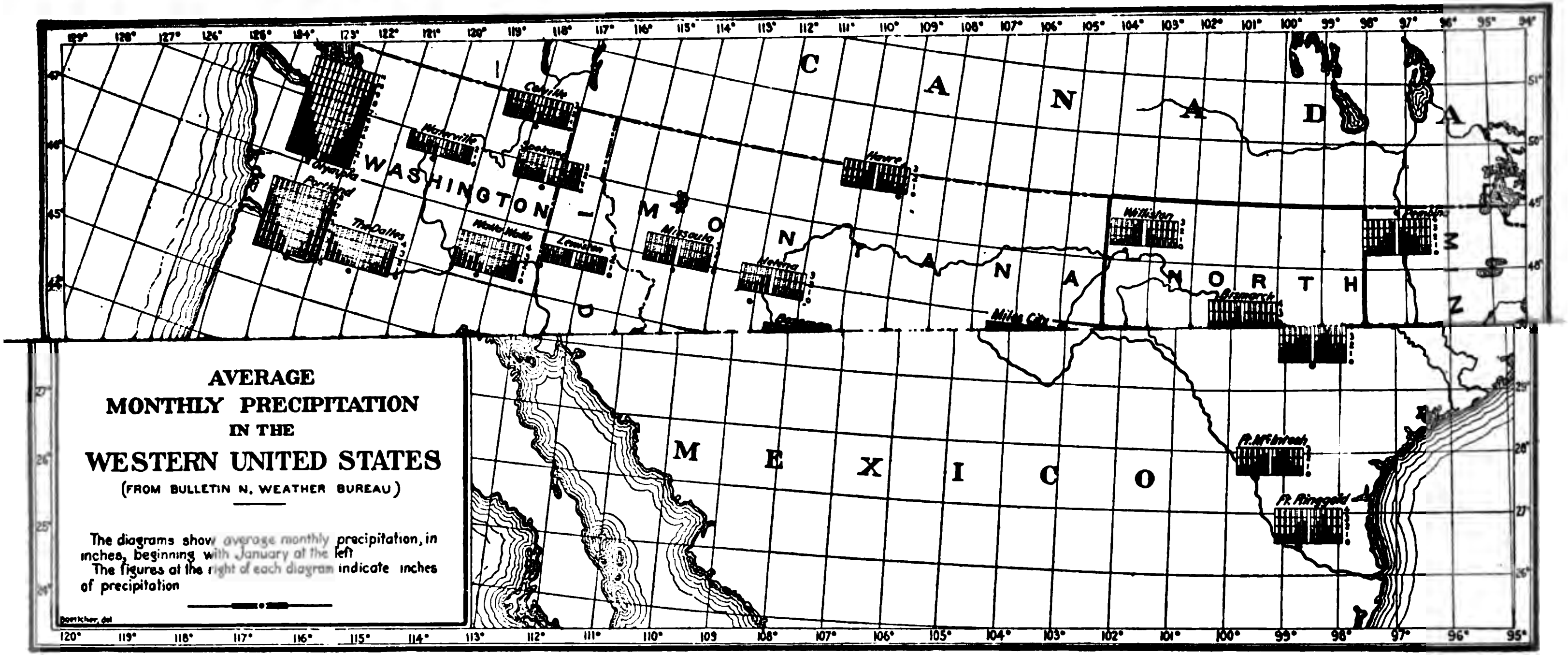

Fig. 3.—Chart Showing the Average Monthly Precipitation at Different Points in the Western United States. The Length of the Black Lines in the Little Diagrams on the Map Shows the Monthly Precipitation, Beginning with January on the Left. A Scale in Inches is Given on the Right of Each Little Diagram.

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DRY FARMING IN RELATION TO RAINFALL AND EVAPORATION.

INTRODUCTION.

This bulletin contains a discussion of dry farming in relation to the amount and character of the rainfall and evaporation in the western United States. Usually in discussing dry-farming conditions the annual precipitation is the only feature of the rainfall that receives attention. But there are other factors in connection with the rainfall that have much to do with the successful production of crops. The seasonal distribution of the rain, the rate at which the rain falls, and the amount of rain that is lost through run-off from the surface all have an important part in determining the percentage of the total rainfall that is really available for the use of crops. Finally, the amount of evaporation which takes place during the growing season determines to some extent the amount of rain that is needed to produce a crop, and this varies greatly in different localities. Prospective settlers in these regions are apt to give very little attention to climatic features other than the total rainfall. They often do not even assure themselves that the figures given for a region represent the normal rainfall and not simply the rainfall for a single year. They ignore almost completely the seasonal distribution of the rain, the frequency of torrential rains, the loss of water through surface run-off, the occurrence of hail, and the amount of evaporation. It is the object of this paper to bring the importance of these factors to the attention of prospective settlers in regions of limited rainfall.

Tables are also appended showing the normal rainfall for practically every station in these regions where precipitation records are available. Accurate information regarding the precipitation in many sections of the West is now available as the result of the extended observations of the United States Weather Bureau. These records, which are often complete for many years and so become of great value to the prospective settler, have been used in computing the rainfall tables which are given in the concluding pages of this bulletin. The precipitation tables are also supplemented by state maps which show at a glance the distribution of the rainfall in the State. Lines showing points of equal annual rainfall have been

All of the results are not, therefore, directly comparable. The measurements at stations printed in heavy-faced type have been made as a part of the physical investigations carried on at the dry-farming stations of the Bureau of Plant Industry and can be directly compared.

TABLE I.—*Evaporation from a tank during the six summer months from April to September, inclusive, at various points in the United States.*

[The figures given represent the total number of inches evaporated during this period.]

State.	City or town.	Number of years.	Date.	Evaporation.
Arizona	Tucson	3	1892-3-4	[a] 54.2
	Yuma	3	1903 [b] 57.8 1904 [c] 53.9 1907 56.4	56.0
California	Calexico	1	1903-4	[d] 71.8
	Kingsburg Bridge	4	1882-3-4-5	[e] 48.2
	Lakeport	2	1901, 1902	[f] 25.3
	Lake Tahoe	2	1900 [g] 20.7 1901 [h] 21.6	21.1
	Pomona	1	1903-4	[d] 44.4
	Sweetwater	5	1889-90-91-92, 1897	[i] 30.0
	Tulare	1	1903-4	[d] 56.6
Colorado	**Akron**	2	1908 to 1909, inclusive	45
	Fort Collins	15	1887 to 1902	[j] 28.3
	Grand Valley	1	1901	[k] 36.5
	Rocky Ford	1	1901	[l] 42.6
Kansas	**Hays**	3	1907 to 1909, inclusive	45.2
	Garden City	2	1908 to 1909, inclusive	50.9
Massachusetts	Boston:			
	Beacon Hill			[m] 25.8
	Chestnut Hill			[n] 23.6
Michigan	Detroit	4	1861 to 1864, inclusive	[o] 32.1
	Monroe	5	1863 to 1867, inclusive	[o] 30.9
	Thunder Bay	4	1862 to 1865, inclusive	[o] 30.2
Montana	**Judith Basin**	1	1909	22.6
Nebraska	Lincoln	11	1899 to 1909, inclusive	[p] 34.8
	North Platte	3	1907 to 1909, inclusive	41.3
Nevada	**Fallon**	2	1908 to 1909, inclusive	51.0
	Reno	2	1894 [q] 37.5 1900 [r] 42.3	39.9
New Jersey	New Brunswick	2	1900-1901 [s] 29.1 1901-2 [t] 29.9	29.5
New Mexico	Carlsbad	1	1899	[u] 54.6
	Las Cruces	3	1899, 1900, 1901	[v] 40.1
New York	Rochester	5		[w] 26.7
North Dakota	**Dickinson**	3	1907 to 1909, inclusive	31.4
	Edgeley	3	1907 to 1909, inclusive	29.5
	Williston	1	1909	30.6

[a] Arizona Agricultural Experiment Station Bulletin 27.
[b] Engineering News, vol. 51, p. 248.
[c] Water-Supply Papers, No. 133, p. 32.
[d] Engineering Record, vol. 51, p. 430.
[e] Water-Supply Papers, No. 81, p. 27.
[f] Idem, p. 32.
[g] Idem, p. 21.
[h] First Annual Report Reclamation Service, 1902, p. 230. Estimated from 5 months' record.
[i] Colorado Agricultural Experiment Station Bulletin 45, p. 26.
[j] Fifteenth Annual Report Colorado Agricultural Experiment Station, p. 205.
[k] Report Irrigation Investigations, Office of Experiment Stations, 1901, p. 284.
[l] Idem, p. 31.
[m] Transactions American Society of Civil Engineers, vol. 15, p. 606 (1868 omitted, the records for that year not being complete).
[n] Idem, p. 618.
[o] Report Chief of Engineers, U. S. Army, 1868, p. 978 (May 4 to October 5).
[p] Nebraska Agricultural Experiment Station. Data furnished by Prof. E. G. Montgomery.
[q] Water-Supply Papers, No. 81, p. 22 (May 11 to October 30).
[r] Report Irrigation Investigations, Office of Experiment Stations, 1900, p. 151 (May 4 to October 24).
[s] Report Irrigation Investigations, Office of Experiment Stations, 1901, p. 353 (April 4 to November 30).
[t] Report Irrigation Investigations, Office of Experiment Stations, 1902, p. 247.
[u] Idem, p. 31 (May 1 to November 11).
[v] New Mexico Agricultural Experiment Station Bulletin 59, p. 43.
[w] Colorado Agricultural Experiment Station Bulletin 45, p. 27.

BLE I.—*Evaporation from a tank during the six summer months from April to September, inclusive, at various points in the United States*—Continued.

State.	City or town.	Number of years	Date.	Evaporation.
io	Cleveland	6	1862 to 1867, inclusive	[a] 24.6
uth Dakota	**Bellefourche**	2	1908 to 1909, inclusive	**38.0**
	Highmore	1	1907	**33.7**
xas	**Amarillo**	3	1907 to 1909, inclusive	**52.4**
	Dalhart	2	1908 to 1909, inclusive	**54.6**
	San Antonio	3	1907 to 1909, inclusive	**45.7**
ah	Corinne	1	1901	[b] 40.1
	Fort Douglas	3	1890-1-2	[c] 30.7
	Logan	1	1901	[d] 34.3
	Nephi	2	1908 to 1909, inclusive	**42.0**
ashington	Prosser	2	1900 24.6 1901 30.6	[b] 27.6
isconsin	Milwaukee	5	1863 to 1867	[e] 26.9
	Stevens Point	2	1901 [f] 28.2 1902 [g] 29.4	28.8
yoming	Laramie	7	1893–1898, 1901	[h] 39.4

[a] Report Chief of Engineers, U. S. Army, 1868, p. 978.

[b] Report Irrigation Investigations, Office of Experiment Stations, 1901, p. 31 (May 18 to November 9). he records for Prosser are for 1900, May 9 to October 29, and 1901, April 22 to October 28.)

[c] Water-Supply Papers, No. 7, p. 20.

[d] Utah Agricultural College Bulletin 80, 1901, p. 77.

[e] Report Chief of Engineers, U. S. Army. 1868, p. 978.

[f] Report Irrigation Investigations, Office of Experiment Stations, 1901, p. 335 (estimated from 3 months' rds).

[g] Report Irrigation Investigations, Office of Experiment Stations, 1902, p. 232 (estimated from 4 months' rds).

[h] For records 1893 to 1898, inclusive, see Water-Supply Papers, No. 81, p. 21.

1893......37.1 inches (estimated from records April 24 to September 30).
1894......38.5 inches (estimated from records April 26 to September 30).
1895......37.1 inches (estimated from records April 17 to September 30).
1896......40.5 inches (estimated from records June 1 to September 30).
1897......42.0 inches (estimated from records April 24 to September 30).
1898......42.3 inches (estimated from records April 15 to September 30).

or records of 1901, see Wyoming Agricultural Experiment Station Bulletin 52, p. 50.

1901......38.2 (estimated from records May 9 to September 30).

The rate of evaporation from a wet soil surface is about the same s from a freely exposed water surface in a tank.[a] Consequently, if he surface of the soil were kept constantly wet the evaporation from he soil would be approximately equal to that found by means of the ank. The fact that we find the evaporation as measured by the ank to be so much greater than the rainfall shows how efficient our ethods of cultivation must be in order that we may have any water t all left for the use of the crop. In a region having an evaporation uring the six summer months of 45 inches and a rainfall of 18 inches, ost of which occurs during the summer, we are able through cultiation to cut the evaporation from the soil down to approximately half the rainfall and so save the remainder of the rainfall for the use of the crop. In establishing a mulch it is necessary to sacrifice all of the moisture in the surface layer of soil that is used to form the mulch. Any rain, then, that simply wets the surface mulch is of no value in storing moisture in summer-tilled land, since it must all be evaporated in order to establish the mulch again.

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[a] This statement must, of course, be considered as only approximate. Very wet, ark-colored soils freely exposed in the sun will usually lose water by evaporation ore rapidly than a free water surface, since the dark soil surface absorbs a larger proortion of the energy from the sun than the free water surface does. The evaporation rom light-colored soils when wet agrees more closely with that taking place from a ee water surface of equal area. As the soils dry out the rate of evaporation gradully decreases. This shows the advantage in using a clean, freely exposed water surace in measuring evaporation, which avoids the errors arising from changes in the ature of the evaporating surface.

EVAPORATION AS INFLUENCING AGRICULTURE IN THE GREAT PLAINS.

The increase in evaporation is very marked as we proceed southward through the Great Plains, the seasonal evaporation in the Panhandle of Texas being 54 inches, or about double that in North Dakota. The influence of this increased evaporation upon the agricultural operations is seen by comparing the agricultural operations along the line of 20-inch annual rainfall in the two States. This line in North Dakota passes through the head of the Red River valley, where the rainfall has been ample for the successful growing of wheat upon the same land year after year. In Texas the 20-inch line passes through a country which is still largely grazing land and where agriculture is confined to the most drought-resistant crops, such as kafir and milo. It is evident, then, that in dry-farming sections having equal rainfall the North has a decided advantage over the South owing to the lower evaporation.

Dr. H. L. Shantz, of the Bureau of Plant Industry, finds that the distribution of a native grass is a good index of the rainfall required in different sections of the Great Plains. Short grass, which consists chiefly of buffalo grass and grama grass, is well suited for this purpose, since it occurs from Montana to Texas. In each section the grass grows as far west as the opposing influences of rainfall and evaporation will permit. Its growth to the east is checked by competition with the prairie grasses. Thus we have a strip of short grass extending from Montana to Texas, limited on the west side by drought and on the east by competition with other grasses. Therefore the increase in the annual rainfall as we go from north to south in the short-grass region represents the additional amount of rain needed to offset the increased evaporation. In Montana, short grass unmixed with other grasses occurs in districts having an annual rainfall of approximately 14 inches; in Colorado, in regions having a rainfall of 17 inches; and in the Panhandle of Texas, in regions having an annual rainfall of 21 inches.[a]

The same type of native grass requires in Texas 7 inches more of rain a year than in Montana. This gives us at once a measure of

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[a] The authors are indebted to Doctor Shantz for this preliminary account of his investigations on the distribution of the vegetation of the Great Plains, which will shortly appear as a bulletin of the Bureau of Plant Industry.

e additional amount of rain required for a grain crop in Texas as
mpared with Montana. Furthermore, the evaporation in Texas
ring the six summer months exceeds that in Montana by about
inches. Therefore, if the summer evaporation at one place in the
reat Plains exceeds that at another by 3 inches a corresponding
crease in the summer rainfall of approximately 1 inch at the first
ace is needed to offset the increased evaporation. A rainfall of 21
ches in the Panhandle of Texas is therefore really no better for
owing crops than 15 inches in Montana or Dakota, owing to the
eatly increased evaporation on the Texas plains.

The influence of the amount of evaporation in different sections of
e Great Plains upon the effectiveness of the rainfall in crop pro-
uction is illustrated in the accompanying chart (fig. 5). The heavy
rved line marked "20" passes through points in the Great Plains
tates having an annual average rainfall of 20 inches. From what
as already been said, it is evident that the conditions determining
rop production become more and more severe as we pass southward
long this line, owing to the increase in the evaporation. It would
herefore be necessary to move more and more to the eastward from
he line representing an annual rainfall of 20 inches as we go south-
ard through the Great Plains, in order to find conditions that are
qually favorable for crop production so far as rainfall is concerned.
he broken line which is coincident with the line of 20 inches annual
ainfall in the northern part of North Dakota and which becomes
nore and more separated from it as we move southward through the
reat Plains passes through points having a rainfall equivalent to
0 inches in North Dakota. The actual rainfall along this line
ncreases as we go south through the area until the lowlands of Texas
re reached, but owing to the increased evaporation it is no more
ffective in growing crops than is 20 inches in North Dakota or
Montana.

To the west of the line of 20 inches annual rainfall will be found second line which passes through points having an average annual rainfall of 15 inches. In connection with this line of 15 inches annual rainfall there is given on the map a second broken line which passes through points having a rainfall equivalent to 15 inches in North Dakota or Montana. It will be noted that through southwestern Nebraska and northwestern Kansas this broken line is practically coincident with the line of 20 inches annual rainfall. In other words, 15 inches of rainfall in Montana or Dakota are equivalent to 20 inches of rainfall in southwestern Nebraska or western Kansas. In southwestern Kansas, eastern Oklahoma, and in Texas this line lies wholly to the east of the line representing 20 inches annual rainfall. Throughout this latter section, then, more than 20 inches of rainfall would be required in order to be equivalent to 15 inches of rainfall along the Canadian boundary. These lines of equivalent rainfall have been established from a consideration of the distribution of the short grass through the Great Plains and from a study of the evaporation. Their position should be considered as only approximate, but they serve to emphasize the great influence of the increased evaporation upon the amount of water required for crop production.

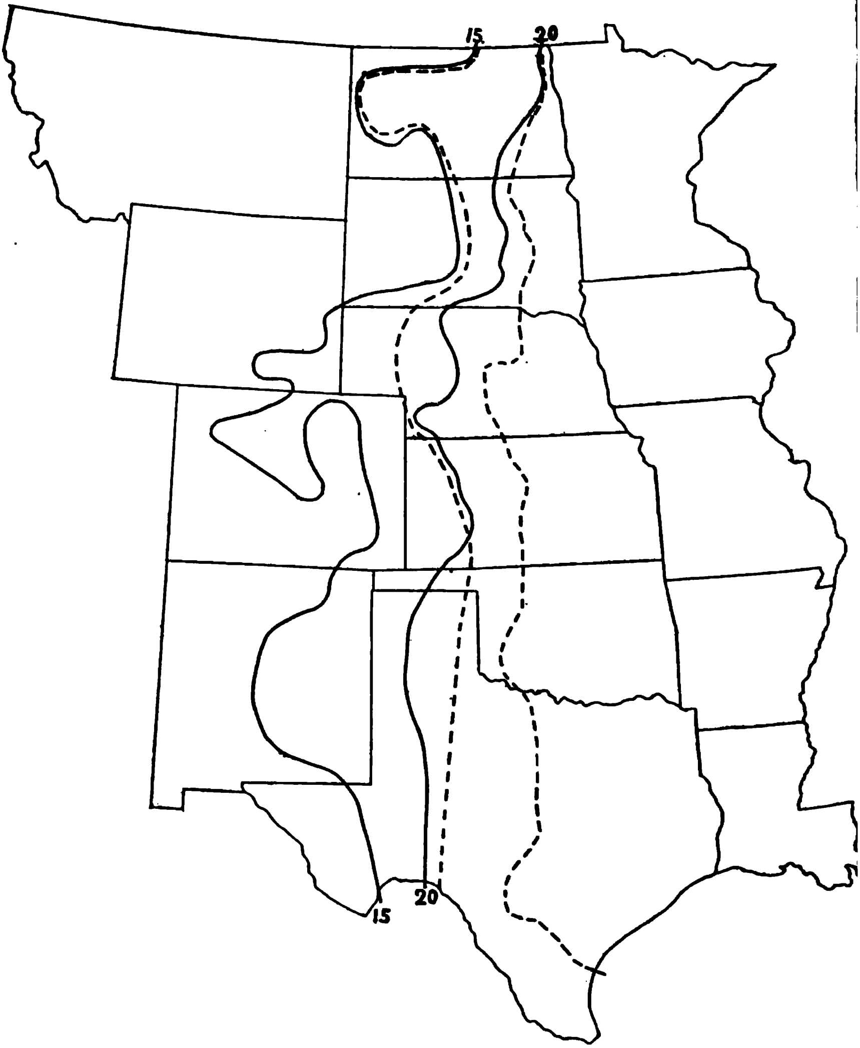

FIG. 5.—Outline map of the States in the Great Plains region, showing the lines of equal rainfall and lines of equivalent rainfall. The solid lines marked 15 and 20 pass through points of equal rainfall; the corresponding dotted lines pass through points having a rainfall which is equivalent to 15 and 20 inches, respectively, on the Canadian boundary.

RELATION OF YIELD TO RAINFALL.

In order that the prospective settler may form an idea of the yields that he can reasonably expect to obtain in regions of limited rainfall, there is given in the following pages a summary of the yields obtained at a number of experimental farms conducted under state and federal supervision.

RELATION OF YIELD TO RAINFALL IN THE GREAT BASIN.

During the years 1904, 1905, and 1906 the Utah Agricultural Experiment Station conducted experiments at six dry-farming stations in Utah.[a] The following table shows the average yield of wheat obtained by summer-fallowing methods at these stations during the three years. The table shows the yearly precipitation, the precipitation that occurred during the growing season from April 1 to July 20, and the corresponding yield.[b] The location of the counties may be seen by referring to the Utah precipitation map, page 44.

TABLE II.—*Relation of precipitation to yield of Lofthouse wheat on summer-fallowed lands at six dry-farming stations in Utah.*

[From Bulletin No. 100, Utah Agricultural Experiment Station.]

County and year.	Yearly precipitation, August 1 to July 31.	Seasonal precipitation, April 1 to July 20.	Yield of wheat per acre.
	Inches.	*Inches.*	*Bushels.*
Iron:			
1904	13.4	3.8	6
1905	9.9	2.8	0
1906	15.9	3.2	7
Juab:			
1904	15.4	3.9	20
1905	11.3	3.1	15
1906	18.4	6.3	31
Tooele:			
1904	18.5	4.6	13
1905	12.4	3.2	11
1906	13.0	4.5	16
Sevier:			
1904	13.2	6.0	8
1905	11.5	4.1	5
1906	15.5	4.6	8
Washington:			
1904	13.4	2.2	2
1905	10.9	2.9	4
1906	16.6	4.1	9
San Juan:			
1904	6.6	2.8	0
1905	19.0	5.3	21
1906	20.0	4.8	29

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[a] Bulletin 100, Utah Agricultural Experiment Station, by W. M. Jardine.

[b] The writers are indebted to Mr. W. M. Jardine for assistance in compiling the yields given in this table. The figures are based upon the average yields of Lofthouse wheat plats and represent in most cases the average of the Lofthouse wheat yields in the variety tests, in the depth-of-plowing tests, and in the time-of-seeding tests, 3 to 5 plats in all. In the depth-of-plowing tests the yield of the plat plowed 8 inches deep was taken when possible, and in the other cases the average of the yields from the plats plowed 5 inches deep and 10 inches deep was used. In the time-of-seeding tests the yields of the plats sown on dates recommended in the bulletin were used. These figures, therefore, represent the yields of wheat grown under conditions generally advocated in the region, viz, on land plowed 8 inches deep and summer-fallowed.

The cost of producing an acre of wheat on summer-fallowed land in Utah, including seed and harvesting, is about $7,[a] which with wheat at 75 cents would be equivalent to about 9 bushels of wheat per acre. On this basis wheat production proved profitable during the three years in Juab and Tooele counties. In San Juan County in 1904 the rainfall was less than 7 inches and the crop was a failure. During the next two years, however, the rainfall was about 20 inches and good yields were obtained. The yields at the other three stations during the three years do not cover the cost of growing the crop. The records of Juab County show clearly the influence of the amount of rain on the yield, the yields varying from 15 bushels with a rainfall of 11 inches in 1905 to 31 bushels with a rainfall of 18 inches in 1906. Jardine emphasizes the importance of having at least 4 inches of rain during the growing season from April 1 to July 20.

To summarize, in Tooele and Juab counties, Utah, profitable yields were obtained when the rainfall exceeded 13 inches. At the other stations in Iron, Sevier, and Washington counties a rainfall of 15 inches was not sufficient to produce profitable crops. The evaporation from a freely exposed tank of water has been found to be about 42 inches during the six summer months in Juab County. We may conclude, then, that with this amount of evaporation an annual rainfall of 13 inches represents about the minimum under which farming can be profitably carried on in the Great Basin.[b]

MINIMUM RAINFALL NECESSARY FOR WHEAT PRODUCTION IN THE COLUMBIA BASIN.

There is probably no other region in the United States where dry farming is successfully conducted with so low a rainfall as in the Columbia Basin, in southern Washington and northern Oregon. This is the result of a combination of favorable conditions. The evaporation is considerably lower than in the Great Basin, the rains come mainly during the winter season and are not torrential, and the basaltic soils absorb the rainfall readily. As we have already seen, the system of alternate cropping and summer fallow is especially adapted to such conditions and is the method uniformly followed in that part of the Columbia Basin where the rainfall is light. Summer tillage of the fallow land is also carried on quite generally throughout the region.[a] The rainfall records in the drier portions of the Columbia Basin are very broken, so that it is not possible at the present time to determine the relation of yield to rainfall with exactness. Hunter,[b] who has made a special study of the conditions in this region, states that while wheat is being produced on an average annual rainfall as low as 8.5 inches, 10 inches is about the minimum for successful wheat production. A great deal of wheat is grown around Ella, in Morrow County, Oregon, and in other parts of the northern tier of counties in Oregon where the rainfall is no greater than that of Ella. The average annual precipitation at Ella, Oreg., during the last ten years has been 9.5 inches. During this period the rainfall has varied from 12.8 inches in 1906 to 5.2 in 1908. During a year of heavy rainfall the yield of the wheat crop grown on summer-fallowed land at Ella is from 20 to 30 bushels per acre, or even more. When the rainfall is 6 or 7 inches the crop is sometimes not worth cutting and the yields are frequently only 6 or 7 bushels per acre. No wheat is grown in the driest part of the basin in the vicinity of Pasco, Wash., where the annual rainfall is only about 6 inches.

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[a] Grace Brothers, who operate a large farm in Juab County, Utah, find the average cost of growing wheat on summer-fallowed land to be $6.85 per acre. This figure includes all charges except an interest charge for the land. (See Second Annual Report Dry-Farming Congress, p. 170.)

The cost of growing spring wheat on fall-plowed land in Minnesota, as given by E. C. Parker and T. P. Cooper, ranges from $4.30 (on a large farm) to $6.40 per acre. These figures do not include land rental or the cost of hauling the grain to market.

Other things being equal, it is to be expected that wheat production under the system of alternate cropping and summer fallowing would be somewhat more expensive than under the annual cropping system, as in Minnesota, owing to the increased cost of maintaining the summer fallow.

[b] Prof. L. A. Merrill, of the Utah station, places the minimum annual rainfall for profitable dry farming in that section at 12 inches.

It appears to be established, then, that wheat is being grown at a profit in this region by summer-fallowing methods on an annual rainfall of 10 inches. The minimum rainfall necessary for a wheat crop that will return more than the cost of production appears to be about 8.5 inches, although actual yields in connection with rainfall records are not yet available to establish this minimum definitely. The yields on the same rainfall of course vary considerably according to the methods and care employed in the production of the crop.

RELATION OF YIELD TO RAINFALL IN THE GREAT PLAINS.

The Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry has been conducting extensive investigations since 1906 to determine the cultural methods and systems of crop rotation best adapted to the conditions in the Great Plains. The following table has been compiled from the results of these experiments, which are now available to the end of the season of 1909.[c] The results of the work cover experiments at eleven stations, extending from Mont to the Panhandle of Texas.

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[a] For a description of the methods of tillage used in this section, see the paper by Byron Hunter, entitled "Farm Practice in the Columbia Basin Uplands," Farmers' Bulletin 294, U. S. Dept. of Agriculture, 1907.

[b] The writers desire to acknowledge their indebtedness to Mr. Byron Hunter, of the Office of Farm Management of the Bureau of Plant Industry, for the information relative to wheat yields in the Columbia Basin.

[c] See "A Study of Cultivation Methods and Crop Rotations for the Great Plains Area," by E. C. Chilcott and members of the field staff of Dry-Land Agriculture Investigations, Bulletin 187, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910.

TABLE III.—*Variation in yield of spring-sown wheat with rainfall in the Great Plains.*

[Based upon the field experiments of the Office of Dry-Land Agriculture Investigations.]

Station and year.	Ordinary methods.	Conservation methods.	Summer tillage.	Rotations, average of 7 plats.	Average yield of 10 plats.	Rainfall, April-July, inclusive.	Rainfall for the year.	Rainfall for the year.		Rainfall the
								Above normal.	Below normal.	Above normal.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*In.*	*In.*	*In.*	*In.*	*In.*
Judith Basin, Mont., 1909	33.0	33.4	34.0	34.6	34.3	14.0	25.6	10.4	......	1.4
Dickinson, N. Dak.:										
1908	24.3	17.7	33.8	28.1	27.3	10.5	19.5	4.5	......	2.3
1909	26.8	25.2	35.7	36.4	34.3	11.2	20.9	5.9	......	3.0
Edgeley, N. Dak.:										
1907	4.1	7.0	9.9	11.1	9.9	6.7	11.5	......	8.0	......
1908	13.3	15.3	16.0	17.1	16.4	9.2	17.1	......	2.5	......
1909	28.3	23.3	27.0	29.7	28.7	10.8	15.6	......	4.1	......
Highmore, S. Dak.:										
1907	28.8	29.7	30.0	28.2	28.6	11.1	17.3	......	.1	.1
1908	26.3	19.7	30.7	25.3	25.4	12.5	22.4	5.0	......	2.1
Bellefourche, S. Dak., 1909	23.8	23.3	32.2	29.1	28.3	7.9	(a)	......	......	......
North Platte, Nebr.:										
1907	24.5	26.0	31.8	23.7	24.8	12.3	19.1	1.0	......	1.2
1908	22.7	27.3	40.5	28.9	29.3	12.8	20.0	1.1	......	1.7
1909	23.0	15.3	18.0	20.1	19.7	13.7	18.9	......	......	2.6
Akron, Colo., 1909	14.3	10.3	18.5	17.0	16.2	10.2	22.4	3.3	......	......
Hays, Kans., 1908	1.2	4.5	4.2	3.8	3.7	14.2	25.3	1.9	......	1.8
Garden City, Kans., 1909	2.1	3.2	6.7	3.0	3.3	11.3	22.0	3.3	......	0.1
Dalhart, Tex., 1909	.0	.0	10.5	1.1	1.8	8.3	16.0	......	......	......
Amarillo, Tex.:										
1908	17.0	14.0	16.0	10.5	12.1	12.6	19.1	......	3.5	1.3
1909	.0	2.8	10.5	1.4	2.3	8.5	18.4	......	4.1	......

[a] Year not complete.

The first column of the table shows the station and State in whic the field work was conducted and the year in which the experiment were carried on; the second column gives the yield of spring whea in bushels per acre under ordinary methods of cultivation—that i shallow spring plowing and no harrowing of the grain after planting the third column, headed "Conservation methods," gives the yield of spring wheat on land plowed 8 inches deep in the fall, put in good tilth in the spring before planting, and harrowed after the grain wa up in order to conserve moisture; the fourth column, headed "Sum mer tillage," gives the yield of spring wheat grown on land summe tilled the preceding year; the fifth column, headed "Rotations," gives the average yield of wheat in seven different rotations carried on at each of the stations; all of the methods employed and the yields obtained are described in detail in the bulletin referred to. In the sixth column is given the average yield of wheat from the ten plats previously considered, namely, the seven rotation plats and three llage plats; in the seventh column is given the rainfall from April July, inclusive, in inches. This period is selected as coinciding ost nearly with the average growing season at the different stations. he eighth column gives the total rainfall for the year, while the last ur columns show the amount that the total rainfall for the year d the season was above or below the normal for that station.

Referring to the last columns of the table, it will be seen that for e 18 series of experiments reported the rainfall for the year in 9 stances was above the normal and in 6 instances below the normal. hile the yields in the greater number of cases have been obtained uring wet years, very trying conditions were encountered at some the stations. At Judith Basin, Mont., and at Dickinson, in the estern part of North Dakota, the rainfall has been unusually high, nging from 5 to 10 inches above the normal. The effect of this is ell exemplified in the yields at Judith Basin, ordinary methods of ltivation giving as good yields with a bountiful rainfall as either nservation or summer-tillage methods. At Dickinson somewhat gher yields were obtained with summer tillage, but not enough to stify this method if the bountiful rains could have been foreseen.

At Edgeley, in the southeastern part of North Dakota, three dry asons were encountered. In the first less than 7 inches of rain fell uring the growing season. The yield on spring-plowed land was 4 ushels per acre; on summer-fallowed land, 10 bushels. In 1908, ith a rain of 9 inches during the growing season, the yields were 13 nd 16 bushels, respectively; and in 1909, with 11 inches of rain dur- g the growing season, the yields were 28 and 27 bushels per acre. he effect of a slightly increased rainfall during the growing season pon the yield is very marked at this station. In 1907, with a sea- onal rainfall of 7 inches, the average yield was about 10 bushels per cre; in 1909, with a seasonal rainfall of 11 inches, the yield was bout 29 bushels per acre, or a gain in yield of 19 bushels for an crease in rainfall of 4 inches.

The results at Edgeley show an increased production on summer- illed land during 1907, which was very dry. It is important to note, owever, that the average yield from the rotation plats was even gher than from the summer-tilled land at this station during this ry year. In fact, the rotations gave better yields than summer- illage methods for each of the three years during which experiments ave been conducted at this station. This indicates that summer illage is not profitable on the soils of the Edgeley district even during ears of deficient rainfall.

An average yield of about 28 bushels was obtained at the Highmore tation in South Dakota during the season of 1907 under a normal ainfall. In 1908 an average yield of 25 bushels per acre was obtained at this station. The rainfall during this year was 5 inches above the normal, but it will be seen from the table that the rainfall during the growing season was only 1.4 inches above that in 1907. The lower yield at Highmore in 1908 is probably to be explained by the fact that the last three weeks of July and the first week of August were very dry, less than 1 inch of rain falling during this time. These results show the necessity of knowing the seasonal rainfall when studying the relation of yield to rainfall in the Great Plains. Frequently, as in this case, a knowledge of the monthly rainfall is not even sufficient, but the daily distribution must be known to determine the influence of the precipitation upon the yield.

At Bellefourche, in western South Dakota, in 1907, a yield of 24 bushels was obtained on spring-plowed land as compared with 32 bushels on summer-tilled land and 29 bushels as the average yield on the rotation plats. These yields were obtained with a rainfall of about 8 inches during the growing season. It will be noted that while summer tillage gave the highest yields, the yield from the rotation plats was nearly as high. Therefore, on the heavy gumbo soils represented by the Bellefourche district, with a seasonal rainfall of 9 inches, the results indicate that crop rotations will give much better returns than summer tillage, considering the fact that a crop on summer-tilled land is obtained only once in two years.

At North Platte, Nebr., the seasonal precipitation has been very uniform for the three years during which experiments have been conducted, varying from 12 to 14 inches. The yield of wheat during these three years, based upon an average of 10 plats, varied from 20 to 29 bushels. We will consider briefly the cause of this fluctuation in yield.

The soil at North Platte is a silt loam of loess formation and absorbs water readily. The season of 1906 was very wet, so that the season of 1907 opened with a good supply of moisture in the soil. Consequently, good yields were obtained in 1907, although the influence of a rather dry spring is shown in the lower yields of the spring-plowed plat.

The fall of 1907 and the spring of 1908 at North Platte were very dry, only 3.5 inches of precipitation occurring from October 1 to May 1. In May, June, and July there was abundant rain. It is under such conditions that moisture-conservation methods become most effective. The moisture stored in the soil by conservation methods is sufficient to carry the crop through a dry spring, and when supplemented by abundant summer rains is sufficient for the production of large crops. Thus, during 1908 a yield of 40.5 bushels was obtained from summer-tilled land as compared with 22.7 bushels from wheat sown on spring-plowed land.

In 1909, on the other hand, the highest yield of wheat at North latte was obtained from spring-plowed land. The seasonal rainll was the highest of any of the three years. But the rainfall was ot the factor which controlled the yields during this season. There as abundant moisture for all the crops. In this case the temperaure was the controlling factor. The wheat sown on the conservaion plats encountered freezing weather for five days just as it was oming up. In the spring-plowed plats, where conditions were not o favorable, the germination was retarded and the plants were not jured during this cold weather. More freezing weather occurred a eek later, which injured the more advanced grain to such an extent hat it never recovered, and the wheat sown on spring-plowed land onsequently gave better yields.

The stations so far considered are located in the central and orthern part of the Great Plains, where the conditions are not so evere owing to the lower evaporation. The remaining stations are ocated in a section subject to high winds, hail, and high evaporation.

At Akron, Colo., in 1909 the spring was cold and wet. Under these onditions we would not expect marked differences between springlowing and summer-tillage methods. The average yield at the staion was about 16 bushels, with a seasonal rainfall of 10 inches.

At Hays, Kans., in 1908 the average yield was only about 4 bushels with a seasonal rainfall of 14 inches. This low yield was due to high winds and dry weather in the spring months. The crop in 1909 was destroyed by hail.

At Garden City, Kans., in 1909 the average yield of wheat was 3 bushels per acre, with a seasonal rainfall of 11 inches. There was 2 inches of precipitation in March, which provided sufficient moisture for the germination of the wheat, but there was practically no precipitation during April and the first half of May, which so weakened the crop that the later rains could not be utilized.

The crop at Dalhart, Tex., in 1908 was destroyed by drought. In 1909 the spring was very dry, less than 3 inches of water falling from September 1 to May 1. Wheat grown on summer-tilled land was the only plat that was able to withstand this weather. A hailstorm on June 19 completed the destruction of those crops that had been weakened by the drought, and injured the wheat on the summer-tilled plat, which, however, gave a yield of 10.5 bushels per acre, with a seasonal rainfall of only 8 inches.

Spring wheat at Amarillo, Tex., during the season of 1907 was a failure, owing to the extremely dry weather of the spring and early summer, combined with the severe hailstorm of June 3. The average yield was only about 2 bushels per acre. In 1908 an average yield of about 12 bushels was obtained on a seasonal rainfall of 12.6 inches. March was very dry during this season, but good rains were recorded in April and May, which explains the equality in yield of the spring-plowed and summer-fallowed plats. In 1909, April and May were very dry, while good rains fell in June. Here again we find the conditions under which conservation methods become especially effective, namely, a dry spring followed by timely summer rains. The wheat sown on spring-plowed land at Amarillo during this season was a failure, while the wheat on summer-tilled land gave a yield of 10.5 bushels on a seasonal rainfall of 8.5 inches.

In comparing the seasonal rainfall with the yields for all the stations it will be seen that when the rainfall from April to July, inclusive, is less than 8 inches the yields are hardly sufficient to cover the expense of producing the crop. With a seasonal rainfall of 8 to 10 inches the yield of wheat grown on summer-tilled land is generally considerably higher than wheat grown on spring-plowed land. When, however, the seasonal precipitation is above 10 or 12 inches, the increased returns from the method of alternate cropping and summer tillage do not exceed the returns from wheat grown in rotation or on spring plowing by an amount sufficient to offset the increased cost of summer tillage.

YIELD IN RELATION TO RAINFALL IN SOUTHERN TEXAS.

THE THREE YEARS' RECORD AT SAN ANTONIO.

Field experiments have also been conducted by the Office of Western Agricultural Extension of the Bureau of Plant Industry, during the past three years, at San Antonio, Tex. The normal rainfall of this region is about 26 inches, but the evaporation is equal to that on the high plains of Texas during the summer months, which, combined with the irregularity of the rainfall, often results in drought. The following table shows the yields of some of the standard crops of this region during three years in which there was a marked variation in the seasonal rainfall.

TABLE IV.—*Relation of yield to rainfall at San Antonio, Tex.*

Crop and year.	Yield per acre.	Seasonal rainfall.	Annual rainfall.
		Inches.	*Inches.*
Corn:			
1907	17.5 bushels	9.3	26
1908	27.4 bushels	10	27
1909	9.9 bushels	4.4	13
Cotton:			
1907	377 pounds	13	26
1908	1,096 pounds	17.7	27
1909	640 pounds	9.3	13
Sorghum:			
1907	3.1 tons	11.3	26
1908	13 tons	16.4	27
1909	1.9 tons	8.2	13

Referring to Table IV, it will be seen that the total rainfall for the year 1909 was only one-half that of either of the two preceding ars, in which the rainfall was about normal. The rain which fell ch year during the growing season of each crop is given in the col- mn headed "Seasonal rainfall."

The seasonal rainfall for corn is taken from March 1 to July 1; cotton, from March 1 to October 1; for sorghum, from April 1 October 1. The cotton yields include weight of both seed and er. The sorghum (Sumac) was grown in drills for forage, and two ttings were made, the total yield being given in the table. The ures in all cases represent the average of a number of plats, varying m 8 to 46 in number each year in the case of the corn and cotton ps and from 3 to 4 in the case of the sorghum.

It will be noted that the yields increase with the seasonal rainfall every instance except that of the cotton crop of 1907. The low eld in this case is due to an extremely dry August and September, ly about 1 inch of rain falling during this time, which is a critical riod in the growth of cotton in this region. The effect of the rain- ll on the growth of sorghum is especially marked, the yield varying m 1.9 tons with a seasonal rainfall of 8 inches in 1909 to 13 tons r acre with a seasonal rainfall of 16 inches in 1908. This latter eld, which is extremely high, was the average of four plats, of which e lowest gave a yield of over 12 tons per acre. All of these four ats were cropped to either sorghum or cotton the previous year, d were plowed the preceding fall in time to take advantage of heavy ll and winter rains. The water which was stored in the soil as the sult of the fall plowing, amounting probably to 6 or 8 inches of rain- ll, was thus available to the crop in addition to the seasonal rain- ll of 16 inches. But even granting that the sorghum had 24 inches water during its growing period and assuming that the forage con- ined 20 per cent of water when weighed, this crop still shows the markable efficiency of 1 pound of dry material produced for every 0 pounds of water used.

SUMMER TILLAGE AT SAN ANTONIO.

The increased yield obtained on summer-tilled land during a dry ason is strikingly illustrated in the results given in Table V, which ere obtained at the San Antonio Experiment Farm in 1909.

ABLE V.—*Comparison of yields from crops grown on summer-tilled land and on land cropped the preceding year at San Antonio, Tex., 1909.*

Crop.	On land cropped in 1908.	On land summer tilled in 1908.
otton	596 pounds	783 pounds.
orn	3.3 bushels	22.6 bushels.
orghum	1.9 tons	5 tons.
ats	0.0 ton	1.25 tons.

Table V shows a comparison of yields obtained on summer-tilled land and on land cropped the preceding year. With the exception of the cotton crop, the increased yield resulting from summer tillage is very marked. The cotton on cropped land was greatly helped by seasonal rains during July and August, a critical period with this crop. The yield of corn on the cropped land was only one-sixth and of sorghum one-third that on summer-tilled land. Oats grown as a hay crop during the winter months were a failure except on the summer-tilled land. These results were obtained during an exceedingly dry year. Usually the rainfall of this region is sufficient to make crop rotations practicable, although cultivated crops should be used as far as possible.

NORMAL PRECIPITATION OF THE WESTERN UNITED STATES.

Table VI has been specially compiled for this bulletin, principally from the numerous reports of the United States Weather Bureau, and includes the rainfall records available to January, 1910. The table gives the station, the county in which the station is located, the elevation of the station above sea level, the normal precipitation[a]—that is, the average annual precipitation for a number of years—and the number of years of records upon which the normal is based, ending with the year given in the table.

In the state rainfall maps (figs. 6–23) each number on the map represents the normal rainfall at the station located at that point. These maps, which were prepared from the figures given in the tables, show the distribution of the rainfall in each State. The heavy curved lines drawn through the maps pass through points having approximately the same rainfall. The amount of rainfall in inches represented by each line is shown by the numbers at the ends of the line. These lines have been drawn when possible to represent differences of 5 inches in the rainfall. For example, in the Kansas map one line passes through points having an annual rainfall of 20 inches, another line through points where the rainfall is 25 inches, and so on. In some States there are found separated regions which have the same rainfall, as in Colorado. These lines have been located by means of the figures given on the map, so that the figures are to be considered rather than the lines. The county boundaries in each State have been revised to date from the maps of the Post-Office Department. The precipitation tables and maps will be found arranged alphabetically according to States.

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[a] The term "precipitation" is used so as to include both rain and snow. The snow that falls into the gauge in the winter is melted, and the water is measured and treated in the records as rain. The records, then, include the total precipitation for the year, whether rain or snow, but measured always as rain.

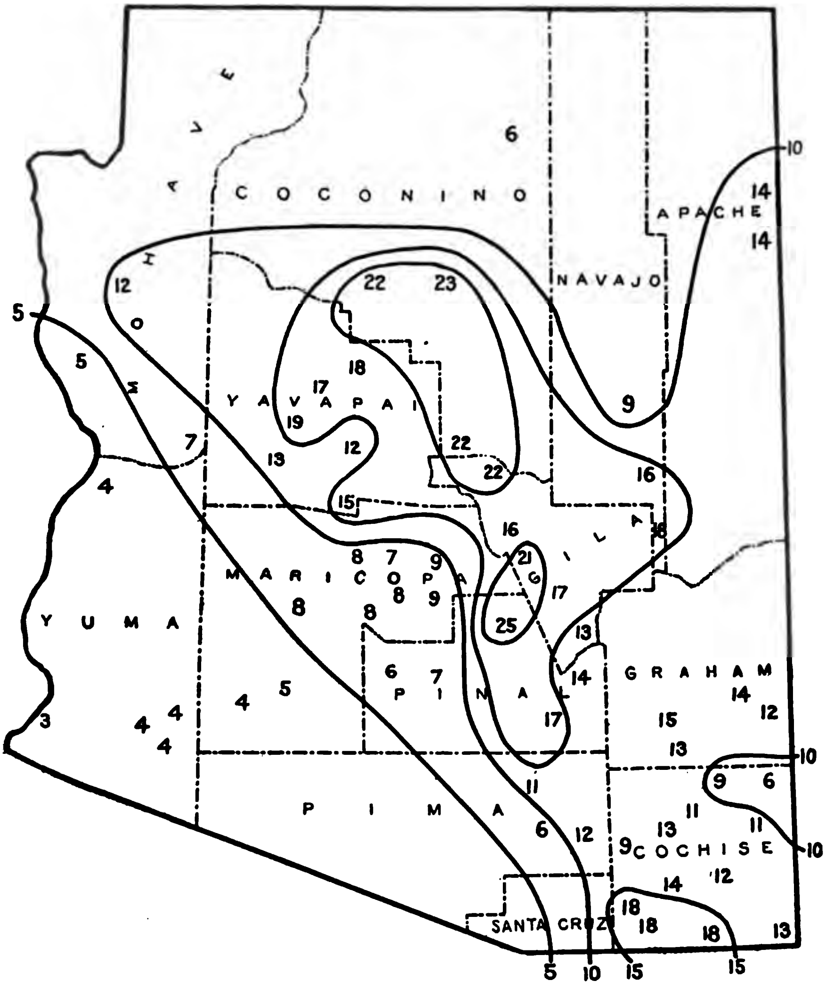

FIG. 6.—Rainfall map of Arizona. The figures show the average annual rainfall in inches.

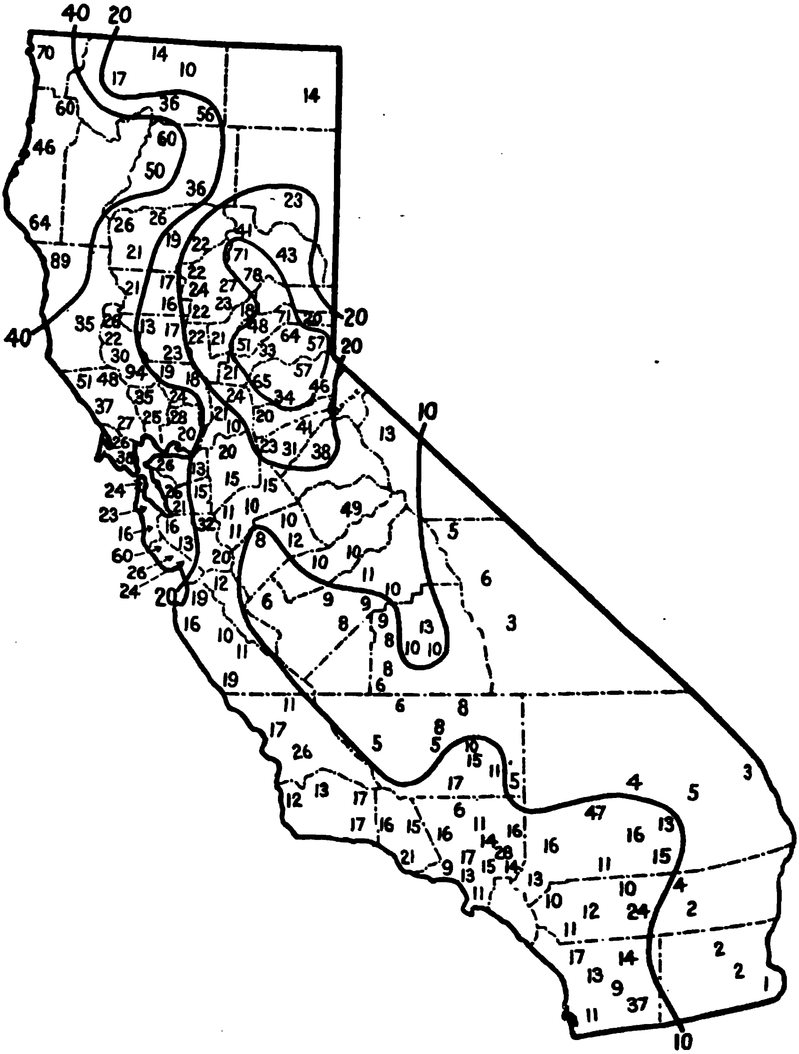

FIG. 7.—Rainfall map of California. The figures show the average annual rainfall in inches.

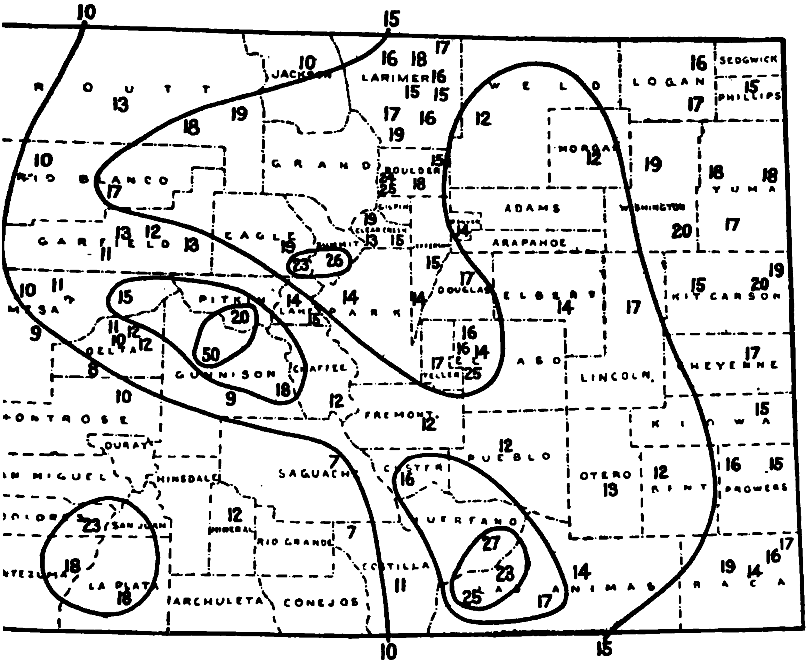

FIG. 8.—Rainfall map of Colorado. The figures show the average annual rainfall in inches.

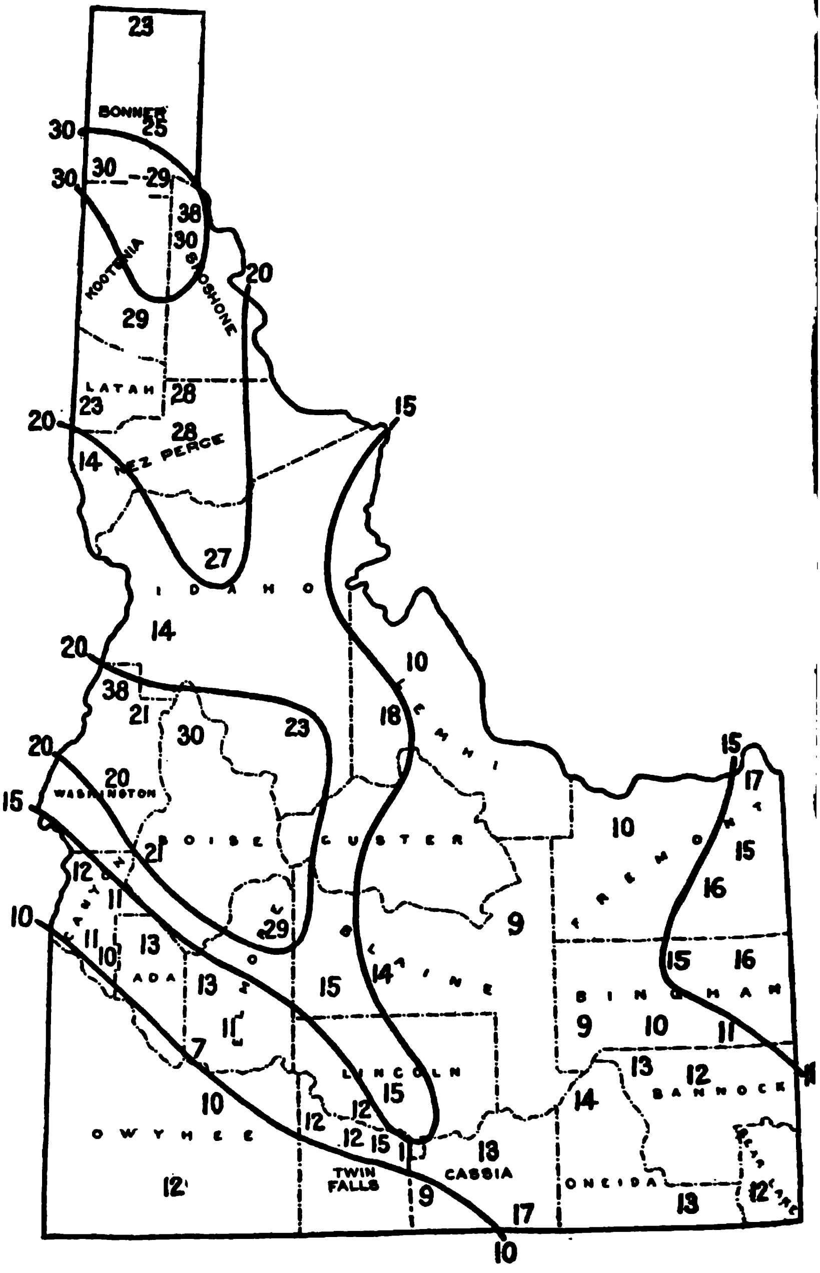

FIG. 9.—Rainfall map of Idaho. The figures show the average annual rainfall in inches.

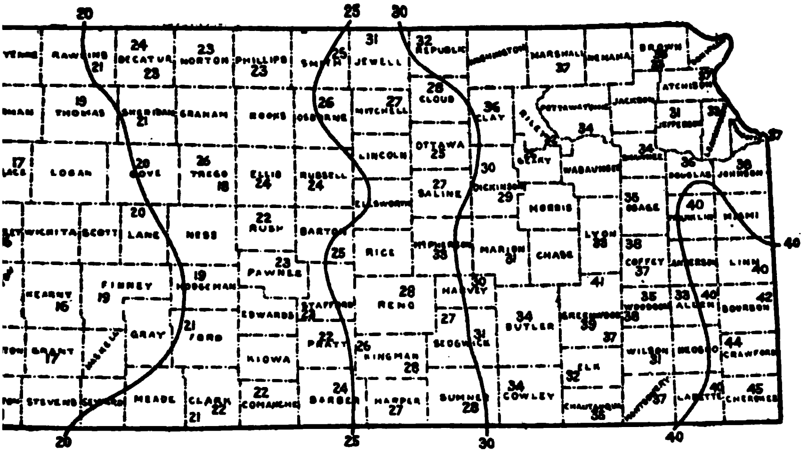

FIG. 10.—Rainfall map of Kansas. The figures show the average annual rainfall in inches.

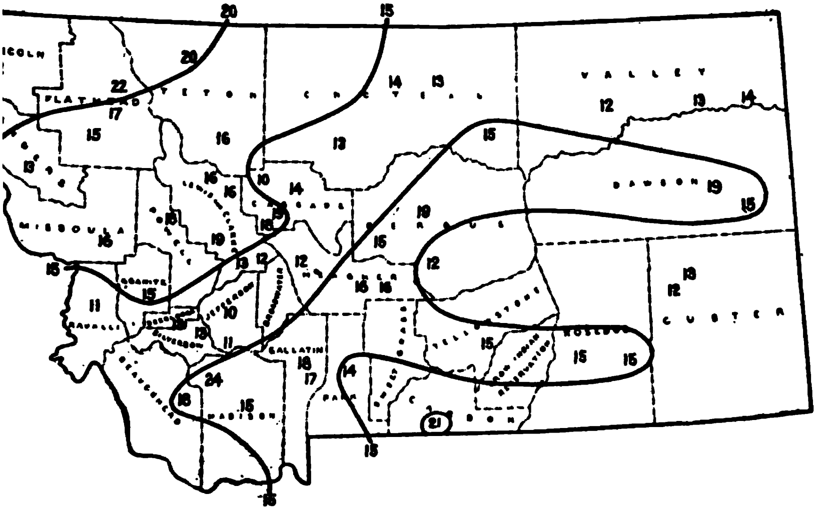

FIG. 11.—Rainfall map of Montana. The figures show the average annual rainfall in inches.

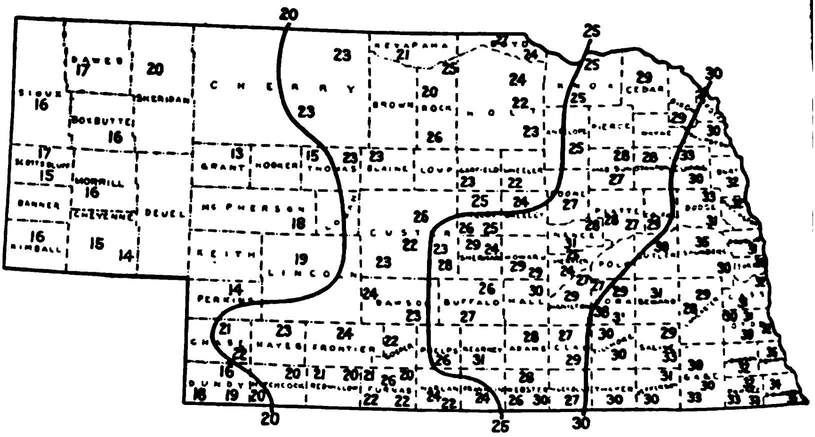

Fig. 12.—Rainfall map of Nebraska. The figures show the average annual rainfall in inches.

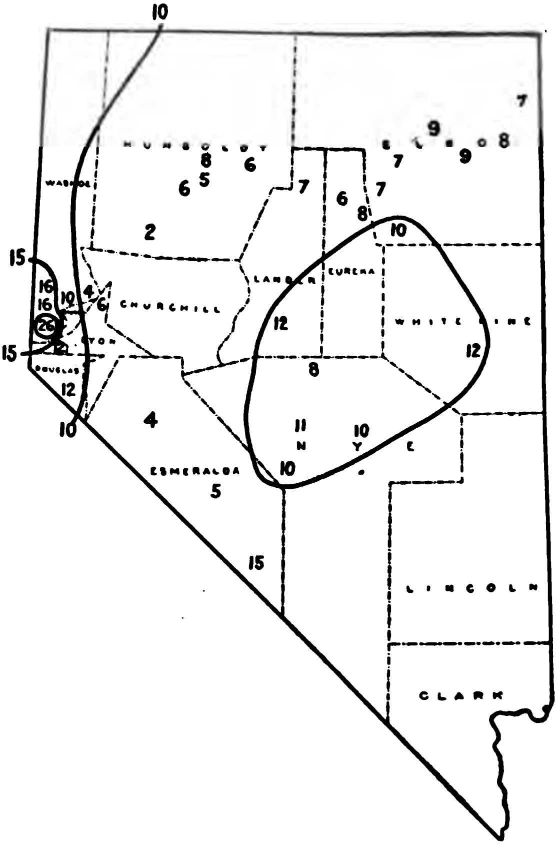

Fig. 13.—Rainfall map of Nevada. The figures show the average annual rainfall in inches.

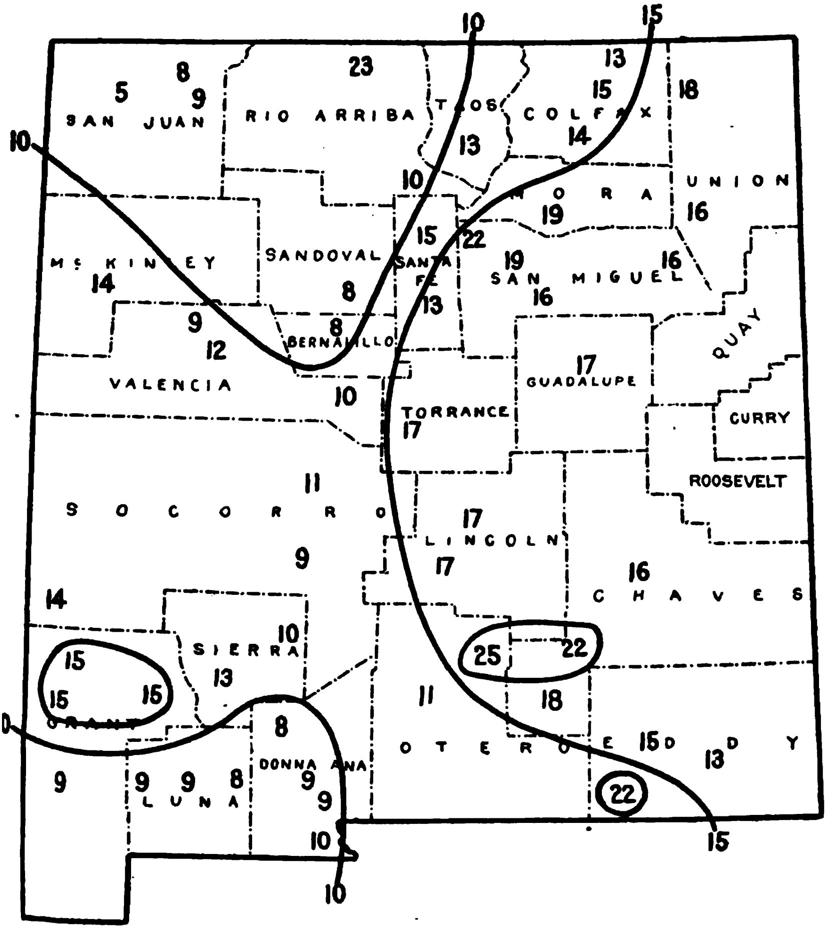

FIG. 14.—Rainfall map of New Mexico. The figures show the average annual rainfall in inches.

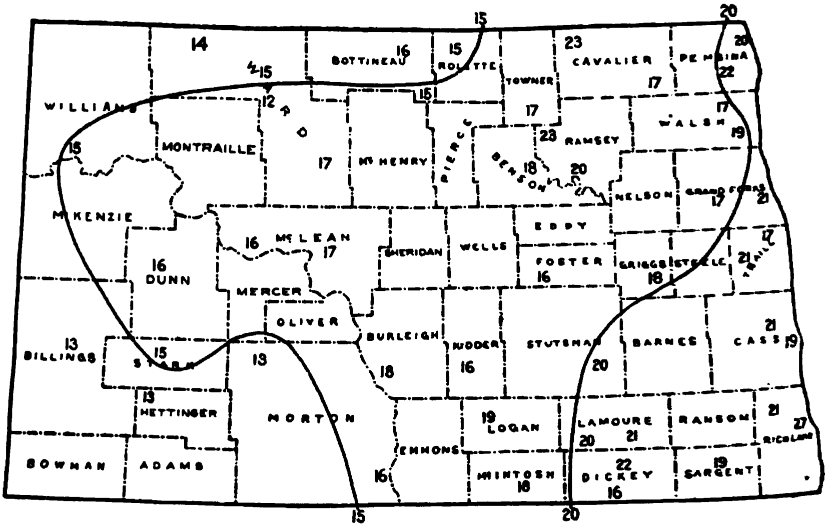

Fig. 15.—Rainfall map of North Dakota. The figures show the average annual rainfall in inches.

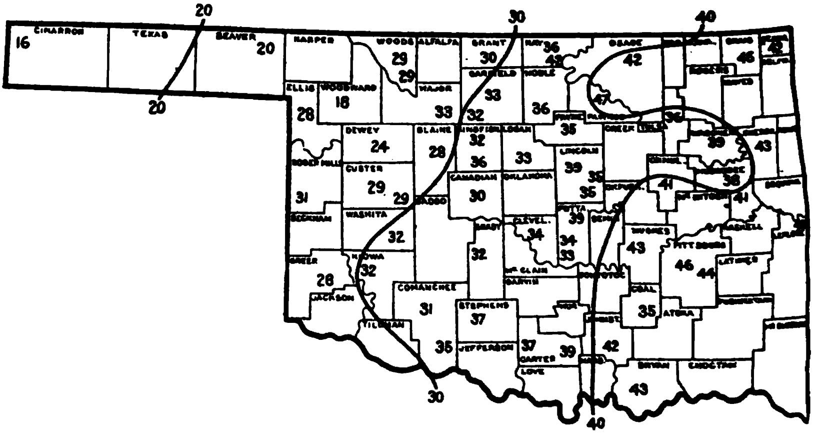

Fig. 16.—Rainfall map of Oklahoma. The figures show the average annual rainfall in inches.

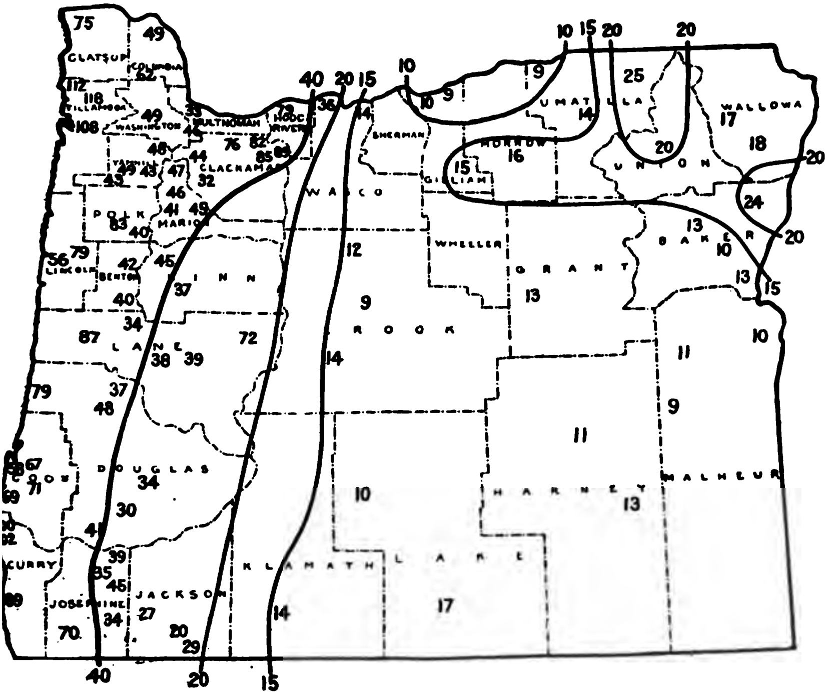

FIG. 17.—Rainfall map of Oregon. The figures show the average annual rainfall in inches.

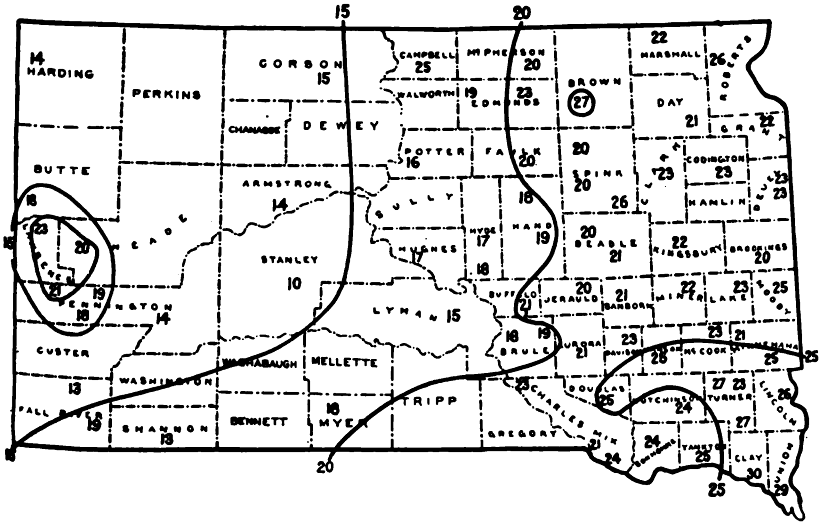

FIG. 18.—Rainfall map of South Dakota. The figures show the average annual rainfall in inches.

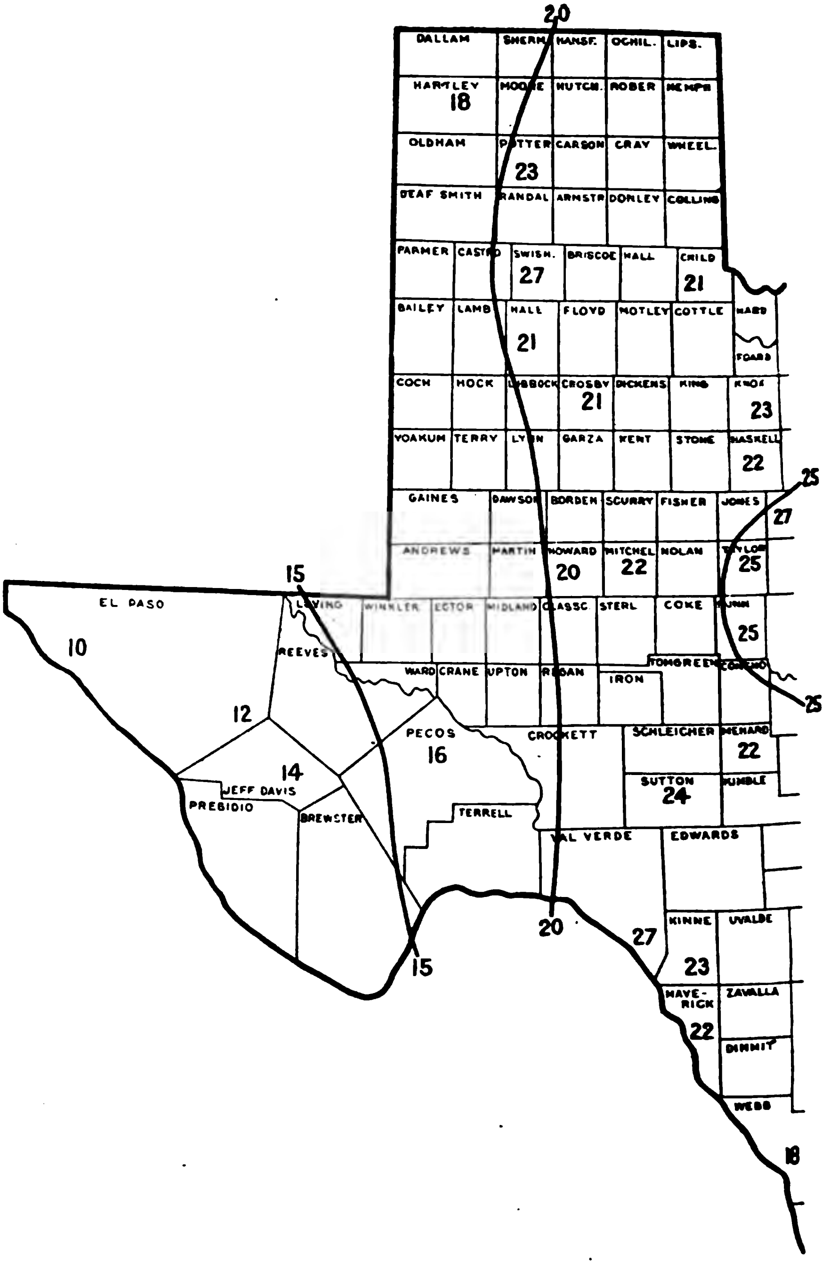

FIG. 20.—Rainfall map of Texas, western part. The figures show the average annual rainfall in inches.

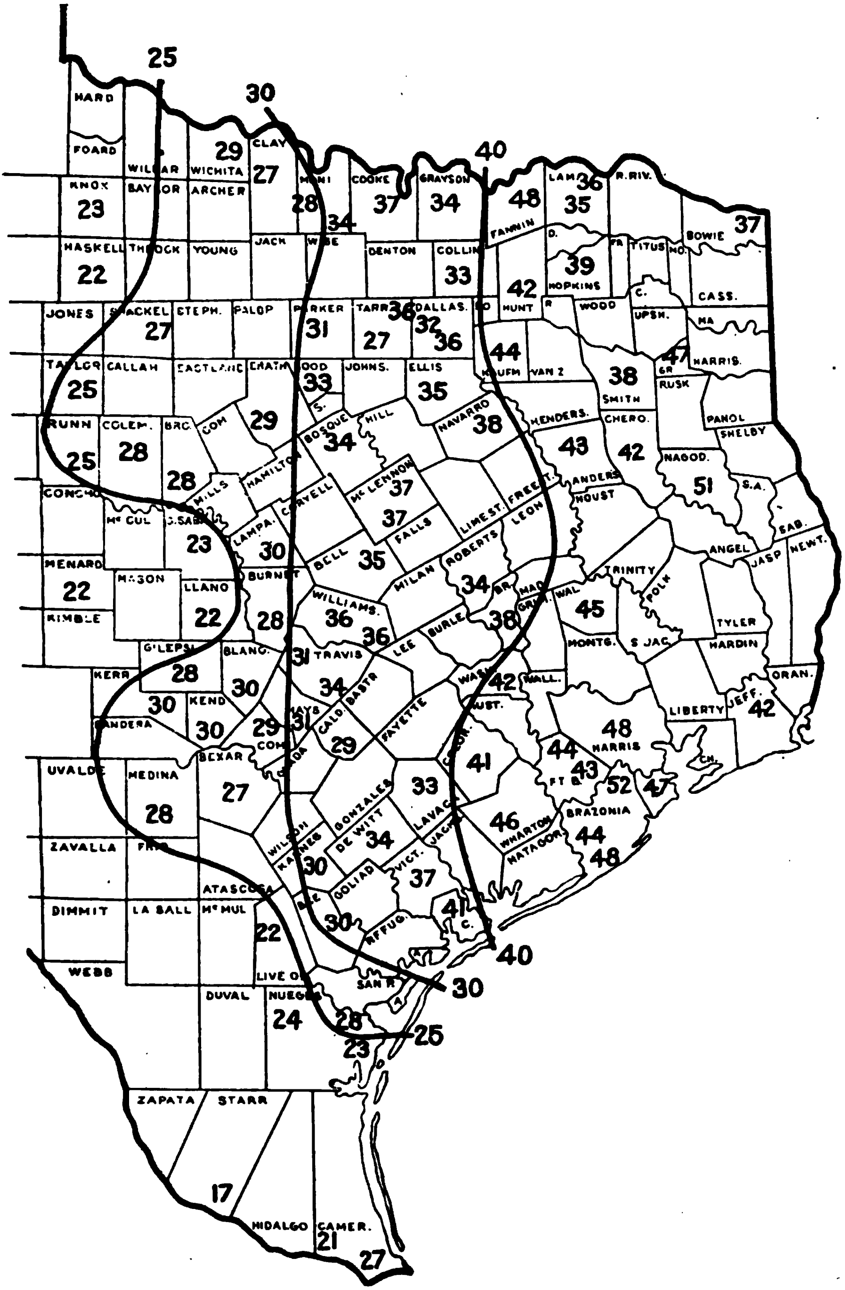

FIG. 19.—Rainfall map of Texas, eastern part. The figures show the average annual rainfall in inches.

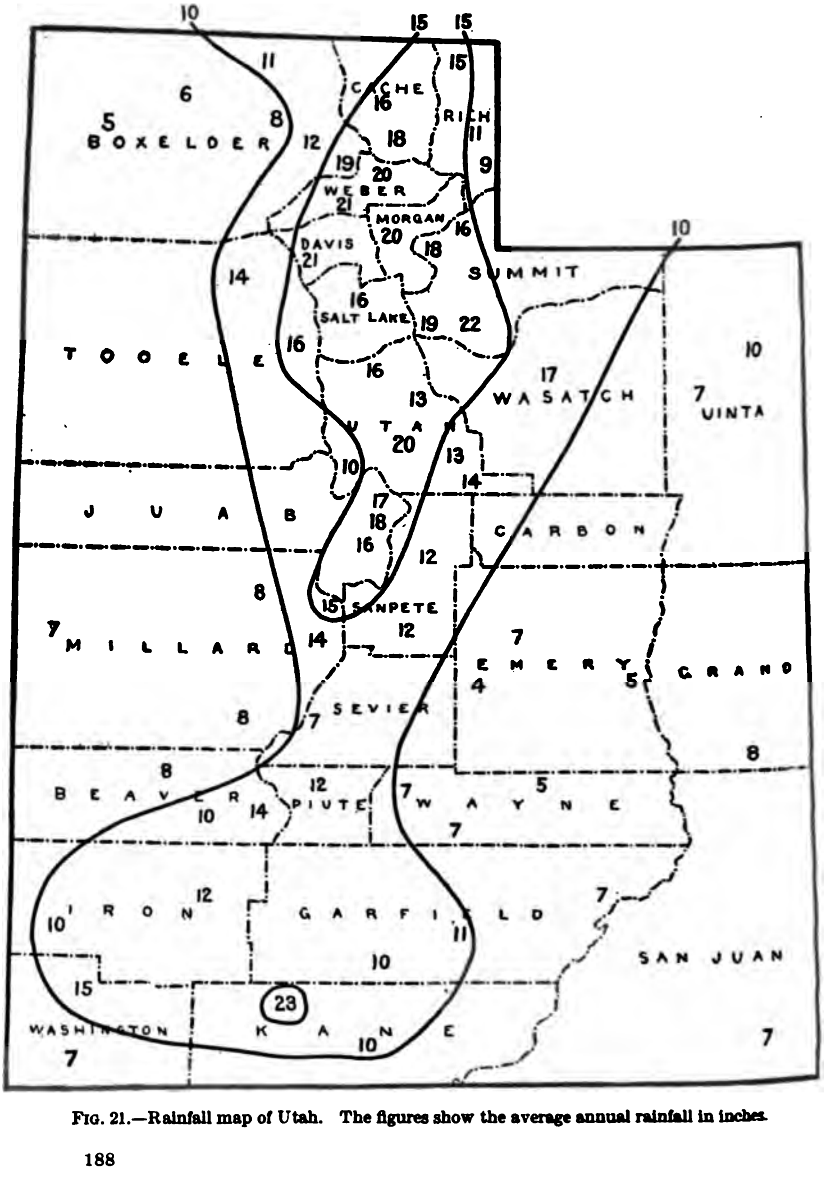

FIG. 21.—Rainfall map of Utah. The figures show the average annual rainfall in inches.

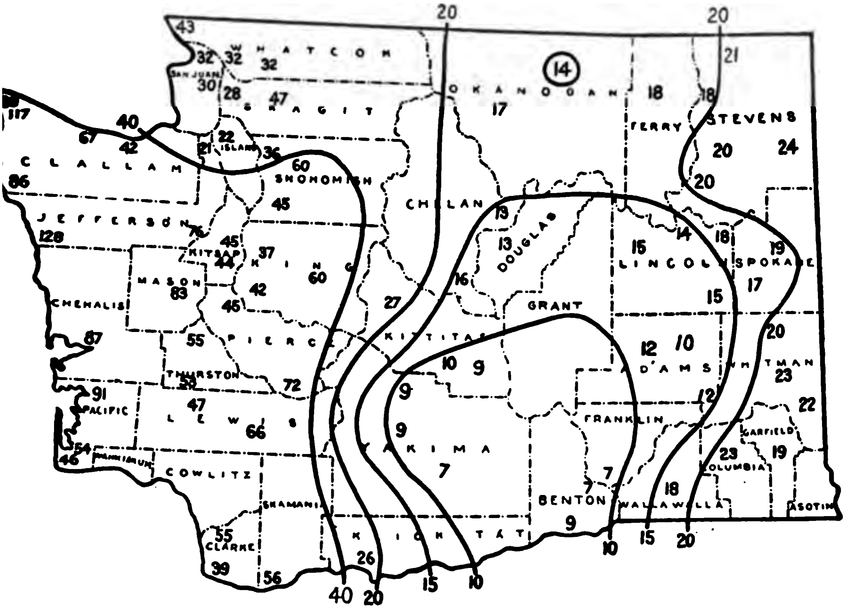

FIG. 22.—Rainfall map of Washington. The figures show the average annual rainfall in inches.

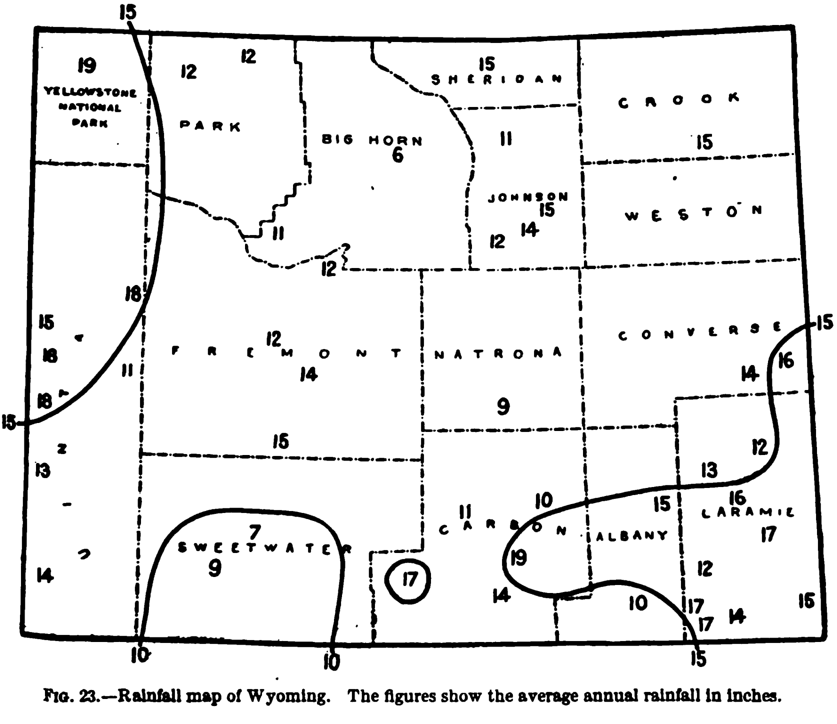

FIG. 23.—Rainfall map of Wyoming. The figures show the average annual rainfall in inches.

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States.*

ARIZONA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation
		Feet.			*Inches.*
Allaires Ranch	Cochise	4,184	12	1908	11.6
Arizona Canal Dam	Maricopa	1,372	16	1908	9.2
Aztec	Yuma	492	10	1908	4.3
Benson	Cochise	3,523	24	1908	9.0
Bisbee	....do	5,500	18	1908	17.7
Bonita	Graham	4,916	28	1908	13.1
Bowie	Cochise	3,756	9	1908	10.5
Buckeye	Maricopa	980	17	1908	7.6
Casagrande	Pinal	1,396	21	1906	7.1
Clifton	Graham	3,610	16	1907	13.8
Cline	Gila	2,300	9	1908	15.9
Cochise	Cochise	4,219	10	1906	10.5
Columbia	Yavapai	1,900	10	1908	15.4
Congress	....do	3,688	12	1908	13.2
Crittenden, Camp	Pima	2,000	5	1872	16.5
Date Creek, Camp	Yavapai	3,726	6	1873	14.2
Douglas	Cochise	3,930	6	1908	13.4
Dragoon	Cochise	4,611	9	1902	12.
Dudleyville	Pinal	2,360	20	1908	14.
Experiment Station Farm	Maricopa	1,092	15	1907	7.
Flagstaff	Coconino	6,907	17	1908	23.
Florence	Pinal	1,553	9	1890	9.
Fort Apache	Navajo	5,200	29	1908	19.
Fort Bowie	Cochise	4,781	23	1890	15.
Fort Defiance	Apache	6,950	8	1905	13.
Fort Grant	Graham	4,916	23	1903	14.
Fort Huachuca	Cochise	5,100	23	1908	15.
Fort Lowell	Pima	2,400	19	1890	12.
Fort McDowell	Maricopa	1,250	24	1890	10.
Fort Mohave	Mohave	604	15	1904	5.
Fort Thomas	Graham	2,700	10	1890	11.
Fort Verde	Yavapai	3,160	22	1890	13.1
Gila Bend	Maricopa	737	18	1908	5.4
Globe	Gila	3,525	6	1908	16.5
Holbrook	Navajo	5,069	19	1908	8.8
Jerome	Yavapai	4,743	12	1908	18.3
Kingman	Mohave	3,326	7	1908	11.8
Maricopa	Pinal	1,186	26	1906	6.0
Mesa	Maricopa	1,244	13	1908	8.6
Mohawk Summit	Yuma	538	7	1907	3.7
Mount Huachuca	Cochise	5,000	12	1902	18.3
Natural Bridge	Gila	4,990	18	1908	21.7
Oracle	Pinal	4,500	13	1906	17.1
Oro	Graham	3,610	11	1904	12.3
Pantano	Pima	3,536	10	1900	12.1
Parker	Yuma	345	10	1905	4.4
Peoria	Maricopa	1,200	9	1900	8.0
Phoenix	....do	1,108	14	1908	7.9
Phoenix (A)	....do	1,092	18	1908	7.5
Pinal Ranch	Pinal	4,520	14	1908	24.9
Prescott	Yavapai	5,660	29	1908	17.3
Roosevelt	Gila	1,983	4	1908	21.2
St. Michael	Apache	6,950	12	1908	13.5
San Carlos	Gila	2,456	21	1908	12.9
San Simon	Cochise	3,609	19	1908	6.4
Sentinel	Maricopa	685	10	1908	3.6
Showlow	Navajo		[a]8	1902	15.8
Signal	Mohave	1,652	16	1908	7.4
Strawberry	Coconino	5,875	5	1901	21.5
Texas Hill	Yuma	353	11	1899	3.5
Tombstone	Cochise	4,550	10	1908	14.2
Tuba	Coconino		7	1906	6.0
Tucson	Pima	2,390	29	1908	10.7
Vail	....do	3,241	10	1908	5.8
Walnut Grove	Yavapai	3,649	14	1908	12.3
Wickenburg	Maricopa	1,400	7	1885	9.9
Willcox	Cochise	4,164	27	1908	8.5
Williams	Coconino	6,750	7	1908	21.5
Yarnell	Yavapai	4,700	11	1908	18.9
Yuma	Yuma	141	28	1908	3.1

[a] Except for December.

BLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

CALIFORNIA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
new	Santa Clara	30	7	1898	13.9
osta	Los Angeles	600	6	1886	25.4
ta	Placer	3,612	16	1885	42.1
aheim	Orange	134	27	1904	11.5
giola	Tulare	208	6	1905	5.6
tioch	Contra Costa	46	29	1907	12.6
tos	Santa Cruz	102	24	1908	25.6
hlone	Merced		5	1890	11.3
burn	Placer	1,360	38	1908	33.5
nza	Los Angeles	540	11	1908	13.9
gdad	San Bernardino	784	6	1908	4.5
kersfield	Kern	404	20	1908	4.8
rstow	San Bernardino	2,105	6	1908	4.1
nicia Barracks	Solano	64	36	1890	16.3
rendo	Madera	256	11	1899	10.1
rkeley	Alameda	317	22	1908	26.4
g Dry Creek	Fresno	435	7	1878	16.6
gs	Butte	98	10	1908	21.8
shop	Inyo	4,450	13	1907	4.7
ne Canyon	Placer	4,695	10	1908	64.1
ca	Nevada	5,531	35	1904	20.1
die	Mono	8,248	12	1906	13.0
rden	Fresno	328	16	1890	9.0
ulder Creek	Santa Cruz	470	11	1899	59.6
wmans Dam	Nevada	5,500	25	1903	71.4
anscomb	Mendocino	2,000	9	1908	88.8
entwood	Contra Costa	80	20	1899	13.5
ighton	Sacramento	53	13	1890	17.2
yron	Contra Costa	33	26	1905	13.0
bazon	Riverside	1,779	13	1908	9.6
liente	Kern	1,290	33	1908	10.6
listoga	Napa	363	37	1908	35.0
mpbell	Santa Clara	217	12	1908	13.2
stroville	Monterey	17	11	1899	17.0
darville	Modoc	4,675	15	1908	13.9
ntral Point	Merced	117	7	1886	9.7
herokee	Butte		11	1884	44.9
hico	do	189	39	1908	22.4
hino	San Bernardino	714	16	1908	13.2
isco	Placer	5,939	39	1908	49.7
laremont	Los Angeles	1,200	17	1908	16.0
loverdale	Sonoma	340	7	1908	47.9
olegrove	Los Angeles	300	8	1890	21.3
olfax	Placer	2,421	39	1908	46.6
olton	San Bernardino	965	28	1904	10.5
olusa	Colusa	60	26	1908	16.6
orning	Tehama	277	23	1908	20.8
raftonville	San Bernardino	1,759	17	1908	13.1
rescent City	Del Norte	50	18	1907	70.2
rystal Springs	San Mateo	220	9	1884	38.2
uyamaca	San Diego	4,677	10	1908	37.4
avisville	Yolo	51	37	1908	16.5
elano	Kern	319	33	1908	6.1
elta	Shasta	1,138	26	1908	60.1
inuba	Tulare	335	6	1899	8.6
rytown	Amador	790	13	1904	29.6
unnigan	Yolo	65	32	1908	19.1
unsmuir	Siskiyou	2,285	20	1908	56.3
urham	Butte	160	25	1908	23.7
ast Brother (L. H.)	Contra Costa	63	15	1890	8.3
dmanton	Plumas	4,730	10	1902	70.7
l Cajon	San Diego	482	9	1908	8.5
l Dorado	Eldorado	1,609	15	1903	37.2
llis	San Joaquin	76	8	1878	8.9
lmira	Solano	75	18	1903	22.3
lmwood	Stanislaus	126	8	1907	10.3
lsinore	Riverside	1,234	14	1908	11.0
l Verano	Sonoma	104	10	1899	36.4
migrant Gap	Placer	5,230	35	1908	51.7
scondido	San Diego	657	21	1908	13.5
ureka	Humboldt	64	23	1908	45.9
xeter	Tulare	392	7	1899	9.5
all Brook	San Diego	700	28	1903	17.3
arallon Island	San Francisco	30	6	1908	18.9
armington	San Joaquin	111	31	1907	16.3

TABLE VI.—*Normal precipitation of stations in the western United States grou according to States*—Continued.

CALIFORNIA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Norm precip tatio
		Feet.			*Inche*
Felton	Santa Cruz	275	10	1899	[illegible]
Fernando	Los Angeles	1,066	26	1903	[illegible]
Firebaugh	Fresno	150	14	1886	[illegible]
Florence	Los Angeles	153	10	1899	[illegible]
Folsom	Sacramento	252	37	1908	[illegible]
Fordyce Dam	Nevada	6,500	14	1908	[illegible]
Fort Bidwell	Modoc	4,640	24	1890	[illegible]
Fort Gaston	Humboldt	397	29	1890	[illegible]
Fort Humboldt	do	50	13	1866	[illegible]
Fort Ross	Sonoma	100	33	1908	[illegible]
Fort Yuma	Imperial	276	28	1883	[illegible]
Fresno	Fresno	293	22	1908	[illegible]
Fruito	Glenn	624	20	1908	[illegible]
Galt	Sacramento	49	31	1908	[illegible]
Georgetown	Eldorado	2,650	36	1908	[illegible]
Gilroy	Santa Clara	193	35	1908	[illegible]
Girard	Kern	3,302	11	1899	[illegible]
Glendora	Los Angeles		5	1899	[illegible]
Gold Run	Placer	3,222	10	1908	[illegible]
Gonzales	Monterey	127	10	1908	[illegible]
Goshen Junction	Tulare	286	21	1899	[illegible]
Grand Island	Colusa	65	6	1899	[illegible]
Grass Valley	Nevada	2,090	25	1899	[illegible]
Grayson	Stanislaus	55	14	1884	[illegible]
Greenville	Plumas	3,600	15	1908	[illegible]
Guadaloupe	Santa Barbara		6	1899	[illegible]
Guinda	Yolo	350	11	1908	[illegible]
Hanford	Kings	249	9	1908	[illegible]
Haywards	Alameda	75	9	1899	[illegible]
Healdsburg	Sonoma	52	16	1908	[illegible]
Helen Mine	Lake	2,750	8	1908	[illegible]
Hollister	San Benito	284	35	1908	[illegible]
Hornbrook	Siskiyou	2,154	19	1907	[illegible]
Humboldt (L. H.)	Humboldt	8	15	1890	[illegible]
Huron	Fresno	367	11	1902	[illegible]
Idyllwild	Riverside	5,250	8	1908	[illegible]
Independence	Inyo	3,907	13	1908	[illegible]
Indio	Riverside	−20	31	1908	[illegible]
Ione	Amador	287	31	1908	[illegible]
Iowa Hill	Placer	2,825	30	1908	[illegible]
Isabella	Kern	2,500	7	1905	[illegible]
Jackson (near)	Amador	1,900	19	1902	[illegible]
Jamestown	Tuolumne	1,471	6	1908	[illegible]
Jolon	Monterey		15	1899	[illegible]
Keeler	Inyo	3,620	24	1908	[illegible]
Keene	Kern	2,705	21	1899	[illegible]
Kennedy Gold Mine	Amador	1,500	11	1902	[illegible]
Kernville	Kern	2,600	5	1899	[illegible]
King City	Monterey	333	22	1908	[illegible]
Kingsburg	Fresno	301	20	1899	[illegible]
Knights Landing	Yolo	45	29	1906	[illegible]
Kono Tayee	Lake	1,325	21	1902	[illegible]
La Grange	Stanislaus	250	23	1890	[illegible]
Lakeport (near)	Lake	1,325	22	1903	[illegible]
La Porte	Plumas	5,000	15	1908	[illegible]
Lathrop	San Joaquin	25	21	1899	[illegible]
Laurel	Santa Cruz	910	11	1899	[illegible]
Le Grand	Merced	255	9	1908	[illegible]
Lemon Cove	Tulare	600	10	1908	[illegible]
Lemoore	Kings	227	20	1899	[illegible]
Lick Observatory	Santa Clara	4,209	28	1908	[illegible]
Livermore	Alameda	485	38	1908	[illegible]
Lodi	San Joaquin	45	21	1908	[illegible]
Los Angeles	Los Angeles	293	32	1908	[illegible]
Los Banos	Merced	121	36	1908	[illegible]
Los Gatos	Santa Clara	600	24	1908	[illegible]
Mammoth Tank	Imperial	257	31	1908	[illegible]
Manzana	Los Angeles	2,850	8	1901	[illegible]
Martinez	Contra Costa	10	21	1899	[illegible]
Marysville	Yuba	67	38	1908	[illegible]
Mendota	Fresno	177	14	1907	[illegible]
Menlo Park	San Mateo	64	31	1908	[illegible]
Merced	Merced	173	35	1908	[illegible]
Milton	Calaveras	660	19	1908	[illegible]
Modesto	Stanislaus	90	38	1908	[illegible]

BLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

CALIFORNIA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
ave	Kern	2,751	31	1907	4.8
elumne Hill	Calaveras	1,550	16	1908	31.2
tague	Siskiyou	2,450	30	1908	10.4
terey	Monterey	15	51	1908	15.6
terio	Kern	4,500	9	1907	16.8
nt Hamilton	Santa Clara	4,440	10	1890	34.3
nt Tamalpais	Marin	2,375	10	1908	28.9
ntain View	Santa Clara		13	1899	16.4
a City	Napa	20	31	1908	25.5
a (S. H.)	do	60	32	1908	25.2
dles	San Bernardino	477	15	1906	2.8
ada City	Nevada	2,580	38	1908	55.8
Almaden	Santa Clara	340	12	1899	23.4
ark	Alameda	25	10	1899	17.7
castle	Placer	970	16	1908	28.8
hall	Los Angeles	1,200	32	1908	15.6
man	Stanislaus	91	20	1908	11.2
laus	Sutter	42	12	1889	18.6
s (near)	Alameda	87	21	1906	19.4
dhoff (near)	Ventura	3,210	8	1905	15.8
th Bloomfield	Nevada	3,200	27	1908	53.5
th Hill Vineyard	Calaveras	660	13	1902	22.5
th Ontario	San Bernardino	1,750	6	1902	16.1
th San Juan	Nevada	2,130	7	1903	47.5
walk	Los Angeles	95	10	1899	11.1
dale	Stanislaus	156	15	1908	15.4
land	Alameda	36	35	1908	25.0
lby	Imperial	354	14	1903	1.1
ta	Amador	1,510	10	1901	37.0
tario (near)	San Bernardino	860	11	1904	12.8
and	Glenn	254	27	1908	17.0
eans	Humboldt	520	6	1908	59.9
ville (near)	Butte	250	25	1908	27.0
aro	Monterey	22	25	1899	19.1
ermo	Butte	213	18	1908	23.1
m Springs	Riverside	584	20	1908	3.7
adena	Los Angeles	828	6	1899	14.5
o Robles	San Luis Obispo	800	22	1908	15.0
chland	Sonoma	190	13	1908	37.4
aluma	do	10	19	1890	23.8
eon Point	San Mateo	150	13	1888	17.8
arcitos	do	620	20	1884	54.8
ot Creek	Eldorado	4,000	5	1899	64.7
e Crest	Santa Barbara	1,000	11	1908	17.3
cerville	Eldorado	1,875	32	1908	45.6
santon	Alameda	353	21	1899	17.2
int Ano Nuevo (L. H.)	San Mateo		15	1890	23.0
int Arena (L. H.)	Mendocino	156	15	1890	30.8
int Bonita (L. H.)	Marin	124	15	1890	24.2
int Conception (L. H.)	Santa Barbara	258	14	1890	13.4
int Lobes	San Francisco	250	16	1908	19.1
rt Los Angeles	Los Angeles	25	6	1899	8.7
int Montara (L. H.)	San Mateo		15	1890	23.8
int Reyes	Marin	490	17	1908	25.8
asky	Fresno	1,200	6	1902	10.5
mona	Lòs Angeles	860	9	1902	14.3
rterville	Tulare	464	20	1908	8.4
way	San Diego	460	25	1908	13.3
nceton	Colusa	57	14	1887	15.2
ente	Los Angeles	320	10	1899	14.0
incy	Plumas	3,400	14	1908	43.2
venna	Los Angeles	2,262	19	1899	10.5
d Bluff	Tehama	307	32	1908	26.1
dding	Shasta	552	34	1908	36.1
dlands	San Bernardino	1,352	16	1908	14.7
edley	Fresno	347	9	1908	10.3
presa	Sacramento	305	12	1904	26.4
ngs Station	San Barnardino	4,300	8	1882	22.5
verside	Riverside	851	27	1908	10.0
o Vista	Solano	28	14	1906	17.6
cklin	Placer	249	38	1908	20.8
sewood	Tehama	865	10	1903	25.9
cramento	Sacramento	71	32	1908	20.9
cramento (2)	do	35	59	1908	19.4

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

CALIFORNIA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Salinas	Monterey	40	35	1908	13.6
San Andreas Reservoir	San Mateo	377	16	1884	46.6
San Ardo	Monterey	236	28	1902	9.7
San Bernardino	San Bernardino	1,054	38	1908	15.8
San Diego	San Diego	93	38	1908	10.5
San Francisco	San Francisco	207	38	1908	24.2
San Gabriel	Los Angeles	452	10	1899	15.3
San Gorgonio Pass	San Bernardino	2,560	10	1887	20.7
San Jacinto	Riverside	1,550	16	1908	11.7
San Jose	Santa Clara	95	34	1908	14.8
San Leandro	Alameda	50	12	1906	22.4
San Luis Obispo	San Luis Obispo	201	14	1908	21.5
San Mateo	San Mateo	22	35	1908	21.7
San Miguel	San Luis Obispo	616	22	1908	10.6
San Miguel Island	Santa Barbara	500	8	1901	10.9
San Pedro	Los Angeles	10	10	1899	11.0
San Rafael	Marin	56	1	1904	37.5
Sanger	Fresno	371	20	1908	10.7
Santa Ana	Orange	137	14	1902	12.1
Santa Barbara	Santa Barbara	130	41	1908	18.6
Santa Clara	Santa Clara	90	27	1908	16.1
Santa Cruz	Santa Cruz	20	31	1908	27.0
Santa Margarita	San Luis Obispo	996	20	1908	26.4
Santa Maria	Santa Barbara	220	23	1908	13.1
Santa Monica	Los Angeles	110	24	1908	13.6
Santa Paula	Ventura	350	15	1903	14.8
Santa Rosa	Sonoma	181	20	1908	30.7
Scott Valley	Siskiyou	2,570	30	1889	25.2
Selma	Fresno	311	23	1908	8.9
Shasta	Shasta	1,049	13	1908	42.9
Shingle Springs	Eldorado	1,415	10	1899	34.4
Sierra Madre	Los Angeles	1,400	12	1908	17.4
Sisson	Siskiyou	3,555	20	1908	36.1
Smartville	Yuba	800	9	1880	30.7
Soledad	Monterey	188	35	1908	9.0
Sonoma	Sonoma	30	18	1906	26.7
South Vallejo	Solano	23	18	1890	15.9
Spadra	Los Angeles	705	15	1890	12.8
Stockton (S. H.)	San Joaquin	23	59	1908	15.6
Storey	Madera	296	9	1908	9.8
Suisun	Solano	20	29	1908	19.9
Summerdale	Mariposa	5,270	12	1907	45.8
Summit	San Bernardino	7,017	38	1906	46.6
Sumner	Kern	422	14	1888	5.1
Susanville	Lassen	4,195	20	1908	22.9
Tehachapi	Kern	3,964	30	1906	10.5
Tehama	Tehama	220	38	1906	15.5
Tejon Rancho	Kern	1,500	7	1905	9.6
Templeton	San Luis Obispo	773	12	1899	17.2
Tennant	Santa Clara	335	7	1885	21.4
Tequisquita Rancho	do	244	8	1906	14.7
Towle	Placer	3,704	23	1908	51.7
Tracy	San Joaquin	64	29	1908	10.1
Traver	Tulare	291	13	1899	8.7
Tropico	Los Angeles	428	11	1899	14.5
Truckee	Nevada	5,819	38	1908	26.9
Tulare (near)	Tulare	274	15	1908	7.7
Turlock	Stanislaus	106	21	1899	10.2
Ukiah	Mendocino	620	32	1906	34.9
Upland	San Bernardino	1,750	12	1906	16.1
Upper Lake	Lake	1,350	24	1908	26.1
Upper Mattole	Humboldt	244	17	1903	63.7
Vacaville	Solano	175	29	1908	27.8
Valley Springs	Calaveras	673	20	1908	22.2
Ventura	Ventura	50	14	1905	21.1
Vina	Tehama	213	14	1902	21.5
Visalia	Tulare	334	21	1908	9.9
Volcano Springs	Imperial	220	17	1905	1.6
Walnut Creek	Contra Costa	75	10	1899	19.6
Wasco	Kern	336	9	1906	4.9
Watsonville	Santa Cruz	23	13	1908	23.8
Weaverville	Trinity	2,162	16	1885	38.3
Westley	Stanislaus	90	20	1908	10.6
West Butte	Sutter	90	10	1889	16.0
West Point	Calaveras	....	6	1899	40.5

E VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

CALIFORNIA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
tland	Yuba	84	22	1908	21.0
tler	Los Angeles	239	14	1902	12.2
ams	Colusa	89	29	1905	12.9
w	Glenn	136	30	1908	15.5
ers	Yolo	136	15	1903	23.6
Bridge	Placer	565	8	1901	33.8
lland	Yolo	63	36	1908	17.7
Buena (L. H.)	San Francisco	345	12	1890	19.4
a	Siskiyou	2,635	29	1901	16.8
City	Sutter	70	11	1902	22.0

COLORADO.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
n	Washington	4,650	6	1908	19.1
d	Larimer		11	1905	17.8
L	Park	10,228	10	1896	14.1
roft	Pitkin	9,483	9	1909	19.7
ne	Baca	3,935	18	1909	15.7
der	Boulder	5,347	14	1909	18.2
Elder	Larimer		12	1902	16.6
kenridge	Summit	9,536	19	1908	25.5
ington	Kit Carson	4,160	7	1909	20.4
on City	Fremont	5,329	21	1909	12.2
le Rock	Douglas	6,220	18	1909	17.2
r Edge	Delta	6,175	11	1902	11.3
sman	Jefferson	6,890	7	1909	14.3
enne Wells	Cheyenne	4,279	16	1909	16.6
r View	Las Animas	9,500	17	1906	22.9
oran	Mesa	6,000	17	1909	15.0
rado Springs	El Paso	6,098	30	1909	14.3
	Washington		13	1909	19.5
ple Creek	Teller	9,396	9	1909	17.2
k	Logan	3,695	7	1899	15.9
a	Delta	4,965	20	1909	8.1
ver	Denver	5,272	38	1909	14.0
nont	Clear Creek	8,000	10	1900	18.6
ango	La Plata	6,534	17	1909	17.8
Collins	Larimer	4,985	28	1909	14.8
Garland	Costilla	7,937	22	1883	12.7
Lewis	La Plata	8,500	10	1890	17.2
Lyon	Bent	4,000	20	1889	11.1
Massachusetts	Huerfano	8,365	6	1858	17.2
Morgan	Morgan	4,319	12	1909	12.3
	Yuma		12	1903	16.6
ita	Mesa	4,510	11	1909	10.3
nett	Costilla	7,576	17	1909	6.6
rgetown	Clear Creek	8,550	8	1909	12.5
nan	Eagle	8,500	14	1903	19.2
n Eyrie	El Paso	6,500	18	1909	15.9
nwood Springs (near)	Garfield	5,823	11	1908	13.1
nd Junction	Mesa	4,608	19	1909	8.5
nd Valley	Garfield	5,089	18	1909	12.6
eley	Weld	4,637	19	1909	12.3
nison	Gunnison	7,670	17	1909	9.3
mps	Elbert	5,400	17	1909	14.0
mosa	La Plata	6,700	7	1882	14.3
ehne (near)	Las Animas	5,700	18	1909	13.9
ly	Prowers	3,386	15	1909	14.8
lyoke	Phillips		7	1902	15.2
go	Lincoln	5,068	7	1901	16.5
sted (near)	El Paso	6,596	18	1904	15.8
ho Springs	Clear Creek	7,543	10	1909	15.1
ke Moraine	El Paso	10,265	16	1909	25.1
mar	Prowers	3,592	20	1909	16.0
Porte	Larimer	5,069	19	1909	15.6
s Animas	Bent	3,899	42	1909	11.7
y	Routt	6,162	16	1909	12.5
dville	Lake	10,248	14	1909	13.8
Roy (near)	Logan	4,380	21	1909	16.5
gmont	Boulder	4,935	8	1896	15.2
ngs Peak (near)	Larimer	8,600	13	1908	19.0
ncos	Montezuma	6,960	11	1909	17.9

TABLE VI.—*Normal precipitation of stations in the western United States according to States*—Continued.

COLORADO—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—
		Feet.		
Meeker	Rio Blanco	6,182	18	1909
Minneapolis	Baca	3,935	9	1899
Montrose	Montrose	5,811	21	1909
Moraine	Larimer	7,775	17	1906
Pagoda	Routt	6,500	19	1909
Paonia	Delta	5,694	15	1909
Parachute	Garfield	5,105	10	1904
Pikes Peak	El Paso	14,134	15	1888
Platte Cannon	Jefferson	5,492	6	1908
Pueblo	Pueblo	4,734	22	1909
Rangeley	Rio Blanco	5,050	11	1909
Red Cliff	Eagle	8,500	7	1896
Rico	Dolores	8,737	6	1896
Rocky Ford (near)	Otero	4,177	21	1909
Rogers Mesa	Delta	5,345	10	1903
Ruby	Gunnison	10,000	8	1902
Saguache	Saguache	7,745	17	1907
Salida	Chaffee	7,035	11	1909
San Luis	Costilla	7,794	19	1909
Santa Clara	Huerfano	8,500	11	1909
Seibert	Kit Carson	4,705	10	1901
Sheridan Lake	Kiowa	4,065	9	1909
Silt (near)	Garfield	5,441	12	1906
Smoky Hill Mine	Boulder	7,800	9	1896
Springfield	Baca	4,400	8	1899
Stamford	Las Animas	9,500	9	1898
Steamboat Springs	Routt	6,683	7	1909
Sugar Loaf	Boulder	7,800	13	1903
Surface Creek	Delta	6,175	6	1897
Thon	Elbert	6,500	9	1896
Trinidad	Las Animas	5,994	12	1906
Twin Lakes	Lake	9,200	9	1902
T. S. Ranch	Mesa	5,200	15	1901
Vilas	Baca	4,155	19	1909
Wagon Wheel Gap	Mineral	8,434	8	1906
Walden	Jackson	....	6	1901
Wallet	Kit Carson	....	8	1902
Waterdale	Larimer	5,206	15	1909
Westcliff	Custer	7,864	16	1909
White Pine	Gunnison	9,500	9	1909
Wray	Yuma	3,512	15	1908
Yuma	....do	4,128	19	1909

IDAHO.

Station.	County.	Elevation.	Number of years recorded.	Record ended—
Albion	Cassia	....	5	1904
American Falls	Oneida	4,341	16	1908
Atlanta	Elmore	7,000	5	1899
Blackfoot	Bingham	4,503	13	1908
Blue Lakes	Lincoln	3,225	2	1904
Boise	Ada	2,770	23	1908
Buhl	Twin Falls	3,800	2	1908
Burnside	Fremont	5,500	11	1903
Caldwell	Canyon	2,372	3	1907
Cambridge	Washington	2,651	13	1908
Chesterfield	Bannock	5,424	12	1908
Dent	Nez Perces	1,350	2	1908
Downey	Bannock	5,425	6	1901
Ellerslie	Elmore	3,500	3	1907
Emmett	Canyon	2,350	2	1908
Forney	Lemhi	....	12	1908
Garnet	Elmore	2,575	9	1908
Grangeville	Idaho	3,500	5	1904
Gray	Bingham	....	3	1899
Hailey	Blaine	5,347	4	1901
Hotspring	Owyhee	2,752	3	1908
Idaho Falls	Bingham	4,742	14	1908
Kellogg	Shoshone	2,330	3	1907
Kootenai	Bonner	1,750	8	1900
Lake	Fremont	6,700	16	1908
Lakeview	Bonner	2,250	12	1908
Landore	Washington	5,300	5	1908

E VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

IDAHO—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
	Boise	5,050	4	1908	29.6
ton	Nez Perces	757	15	1908	13.5
River	Blaine	5,700	14	1908	9.4
ows	Washington	3,950	6	1908	21.2
r	Twin Falls	4,097	5	1908	11.0
ow	Latah	2,748	16	1908	22.6
tainhome	Elmore	3,150	3	1908	11.3
ay	Shoshone	2,750	15	1908	37.6
augh	Twin Falls		2	1908	15.4
ey	Cassia	4,191	16	1908	9.3
	Boise	3.100	11	1905	21.0
no	Nez Perces	1,027	5	1908	28.4
	Bear Lake	5,946	12	1908	12.2
tte	Canyon	2,159	16	1908	12.0
tello	Bannock	4,483	9	1908	12.9
ck	Idaho	2,050	9	1904	14.3
ars	Canyon	2,425	8	1908	10.3
ill	Bonner	1,665	16	1908	23.0
t River	do	2,078	8	1905	29.5
le	Owyhee	6,200	3	1903	12.1
evelt	Idaho	7,250	4	1906	23.4
ert	Lincoln	4,204	2	1908	15.1
laries	Kootenai	2,062	12	1908	28.7
n	Fremont	5,000	3	1907	16.0
on	Lemhi	4,040	3	1908	10.4
ler	Blaine	5,140	14	1908	14.9
drod	Cassia		3	1908	17.3
a Valley	Bingham	5,434	5	1899	15.8
a Falls	Twin Falls	3,825	3	1908	12.4
on	Fremont		12	1908	14.5
ton	Oneida	4,460	8	1905	13.1

KANSAS.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
ene	Dickinson	1,157	21	1907	29.7
illes	Rawlins	2.827	12	1904	20.9
cultural College	Riley	1,100	50	1908	30.2
ona	Wilson	815	10	1901	31.4
hony	Harper	1,329	11	1907	26.6
land	Clark	1,951	22	1908	21.9
hison	Atchison	973	23	1907	37.4
er	Brown	1,182	8	1908	34.9
it	Mitchell	1,383	10	1903	26.7
lington	Coffey	1,010	15	1908	37.4
Center	Clay	1,203	7	1908	35.5
by	Thomas	3,138	22	1908	19.4
lwater	Comanche	2,090	11	1908	22.0
mbus	Cherokee	898	19	1908	44.5
cordia	Cloud	1,398	24	1908	27.5
lidge	Hamilton	3,346	11	1908	15.8
ningham	Kingman	1,680	24	1907	25.5
ge City	Ford	2,513	34	1908	20.8
sden	Decatur	2,731	14	1908	23.0
lorado	Butler	1,291	6	1908	34.0
nwood	Barton	1,788	22	1908	24.5
poria	Lyon	1,138	25	1908	33.3
lewood	Clark	1,955	14	1906	21.0
erprise	Dickinson	1,144	6	1908	28.8
eka	Greenwood	1,093	14	1908	38.6
l River	do	925	12	1908	36.5
nsworth	Lane	2,850	8	1908	20.3
rt Leavenworth	Leavenworth	788	50	1905	32.6
rt Riley	Geary	1,070	4	1898	25.9
rt Scott	Bourbon	857	16	1908	42.4
nkfort	Marshall	1,146	14	1908	36.6
rden City	Finney	2,836	22	1908	18.8
son	Trego	2,475	10	1899	17.5
ve	Gove	2,750	22	1908	20.4
enola	Elk	1,116	21	1908	32.2
rrison	Jewell	1,804	7	1908	30.9
ys	Ellis	2,000	39	1908	23.5
rton	Brown	1,188	19	1908	33.1

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

KANSAS—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Hoxie	Sheridan	2,700	11	1908	
Hutchinson	Reno	1,535	18	1908	
Independence	Montgomery	816	36	1908	
Iola	Allen	984	3	1908	
Jetmore	Hodgeman	2,268	7	1908	
Kansas City (Mo.)	Jackson	1,029	21	1908	
Lacrosse	Rush	2,061	6	1908	
Lawrence	Douglas	874	41	1908	
Lebo	Coffey	1,138	22	1908	
Lakin	Kearney	2,993	18	1908	
Larned	Pawnee	2,090	13	1907	
Lebanon	Smith	1,812	10	1908	
McPherson	McPherson	1,495	18	1908	
Macksville	Stafford	2,032	15	1908	
Madison	Greenwood	1,074	7	1908	
Manhattan	Riley	1,014	18	1908	
Marion	Marion	1,310	15	1908	
Medicine Lodge	Barber	1,475	13	1905	
Minneapolis	Ottawa	1,259	19	1908	
Moran	Allen	1,098	13	1908	
Mount Hope	Sedgwick	1,410	11	1908	
Newton	Harvey	1,454	11	1908	
Norton	Norton	2,284	10	1908	
Norwich	Kingman	1,496	12	1908	
Oberlin	Decatur	2,539	21	1907	
Olathe	Johnson	1,032	14	1908	
Osage City	Osage	1,081	11	1908	
Osborne	Osborne	1,557	21	1904	
Oswego	Labette	899	19	1908	
Ottawa	Franklin	926	14	1908	
Phillipsburg	Phillips	1,939	22	1908	
Pleasanton	Linn	862	6	1908	
Pratt	Pratt	1,950	13	1908	
Republic	Republic	1,495	6	1908	
Rome	Sumner	1,218	22	1908	
Russell	Russell	1,834	6	1908	
Salina	Saline	1,227	24	1908	
Sedan	Chautauqua	834	23	1908	
Topeka	Shawnee	992	22	1908	
Toronto	Woodson	1,040	11	1908	
Tribune	Greeley	3,650	....	1900	
Ulysses	Grant	3,027	11	1908	
Valley Falls	Jefferson	913	9	1908	
Viroqua	Morton	3,215	12	1904	
Wakeeney (near)	Trego	2,456	7	1907	
Wallace	Wallace	3,303	39	1908	
Walnut	Crawford	940	6	1908	
Wamego	Pottawatomie	1,002	14	1908	
Wichita	Sedgwick	1,377	21	1908	
Winfield	Cowley	1,124	11	1908	
Yates Center	Woodson	1,068	27	1908	

MONTANA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
Adel	Cascade	5,200	9	1907	
Agricultural College	Gallatin	4,700	11	1908	
Anaconda	Deer Lodge	5,300	7	1908	
Augusta	Lewis and Clark	4,071	10	1908	
Billings	Yellow Stone	3,115	9	1908	
Boulder	Jefferson	4,904	12	1905	
Bozeman	Gallatin	4,700	5	1897	
Busby	Rosebud	....	6	1908	
Butte	Silver Bow	5,716	15	1908	
Canyon Ferry	Lewis and Clark	3,644	10	1908	
Chinook	Chouteau	2,502	9	1906	
Chouteau	Teton	....	6	1897	
Columbia Falls	Flathead	3,098	3	1908	
Crow Agency	Rosebud	3,041	26	1908	
Culbertson	Valley	1,927	6	1906	
Dayton	Flathead	....	5	1908	
Dearborn Canyon	Lewis and Clark	4,590	6	1898	
Dillon	Beaverhead	5,147	9	1908	

ABLE VI.—*Normal precipitation of stations in the western United States according to States*—Continued.

MONTANA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—
		Feet.		
ort Benton	Chouteau	2,630	29	1908
ort Keogh	Custer	2,350	22	1899
ort Logan	Meagher	6,000	15	1902
ort Shaw	Cascade	3,500	22	1908
lasgow	Valley	....	7	1900
lendive	Dawson	2,069	19	1907
reat Falls	Cascade	3,350	18	1908
lamilton	Ravalli	3,575	6	1908
lavre	Chouteau	2,505	29	1908
lelena	Lewis and Clark	4,110	29	1908
logan	....do	4,590	6	1897
alispell	Flathead	2,965	10	1908
ipp	Teton	4,472	6	1899
ewistown	Fergus	4,010	11	1908
ivingston	Park	4,488	12	1908
lartinsdale	Meagher	4,800	11	1901
larysville	Lewis and Clark	5,370	13	1906
liles City	Custer	2,371	17	1908
lissoula	Missoula	3,225	28	1907
vando	Powell	4,207	8	1907
hilipsburg	Granite	5,273	5	1908
lains	Sanders	2,473	10	1908
oplar	Valley	2,020	24	1908
ed Lodge	Carbon	5,548	8	1908
enova	Jefferson	4,383	10	1908
pringbrook	Dawson	....	7	1908
t. Pauls	Chouteau	4,150	9	1904
t. Peter	Cascade	4,500	5	1905
roy	Lincoln	1,881	14	1908
winbridge	Madison	4,650	4	1905
wo Dot	Meagher	4,800	12	1902
tica	Fergus	5,000	15	1908
irginia City	Madison	5,880	18	1897
ale	Fergus	3,990	11	1905

NEBRASKA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—
gate	Sioux	....	7	1906
gee	Holt	....	12	1903
lbion	Boone	1,747	11	1906
lliance	Boxbutte	3,968	11	1906
lma	Harlan	1,939	12	1909
noka	Boyd	....	3	1909
nsley	Custer	2,307	15	1904
rapahoe	Furnas	2,173	7	1901
rborville	York	....	11	1902
rcadia	Valley	2,186	10	1909
shland	Saunders	1,120	26	1909
shton	Sherman	2,061	15	1908
uburn	Nemaha	1,051	17	1909
urora	Hamilton	1,792	13	1908
artley	Redwillow	2.325	6	1904
assett	Rock	2,323	6	1896
eatrice	Gage	1,247	18	1909
eaver City	Furnas	2,147	18	1909
ellevue	Sarpy	1,210	27	1909
enkelman	Dundy	2,968	9	1903
lair	Washington	1,122	14	1909
luehill	Webster	1,967	14	1908
radshaw	York	1.715	11	1909
ridgeport	Morrill	3.800	13	1909
rokenbow	Custer	2,477	14	1909
urchard	Pawnee	1,377	14	1908
urwell	Garfield	2,180	17	1907
allaway	Custer	2,555	12	1906
ambridge	Furnas	2.258	2	1909
entral City	Merrick	1,708	11	1900
olumbus	Platte	1,441	16	1909
reighton	Knox	1,600	11	1899
rete	Saline	1,368	26	1909
ulbertson	Hitchcock	2,565	21	1908
urtis	Frontier	2,553	10	1905

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

NEBRASKA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
David City	Butler	1,607	20	1909	28.1
Dawson	Richardson	945	16	1909	34.0
Duff	Rock		10	1908	25.5
Edgar	Clay	1,722	15	1909	28.2
Ericson	Wheeler	2,029	14	1904	22.4
Ewing	Holt	1,888	17	1909	23.4
Fairbury	Jefferson	1,316	34	1909	30.4
Fairmont	Fillmore	1,641	16	1909	28.6
Franklin	Franklin	1,817	18	1909	23.8
Fremont	Dodge	1,203	29	1909	30.5
Fort Robinson	Dawes	3,764	25	1909	16.9
Fullerton	Nance	1,629	7	1909	21.2
Geneva	Fillmore	1,633	19	1909	30.1
Genoa	Nance	1,584	34	1909	27.9
Gering	Scottsbluff	3,902	18	1908	14.4
Gosper	Gosper		7	1909	22.3
Gothenburg	Dawson	2,557	15	1909	21.5
Grand Island	Hall	1,861	18	1909	28.7
Greeley	Greeley	2,021	14	1909	25.6
Guiderock	Webster	1,546	9	1909	30.0
Haigler	Dundy	3,256	11	1902	17.8
Halsey	Thomas	2,695	7	1909	21.4
Hartington	Cedar	1,309	18	1909	28.0
Harvard	Clay	1,799	20	1909	27.3
Hastings	Adams	1,932	19	1909	27.7
Hayes Center	Hayes		16	1909	22.8
Hay Springs	Sheridan	3,821	22	1909	20.1
Hebron	Thayer	1,458	24	1909	29.6
Holbrook	Furnas		5	1906	25.3
Holdrege	Phelps	2,324	17	1909	25.9
Hooper	Dodge	1,228	12	1909	27.9
Imperial	Chase	3,278	19	1909	20.9
Kearney	Buffalo	2,147	19	1909	26.9
Kennedy	Cherry		16	1906	21.0
Kimball	Kimball	4,697	20	1909	15.7
Kirkwood	Rock		14	1909	25.2
Lexington	Dawson	2,385	20	1909	23.0
Lincoln	Lancaster	1,189	30	1909	27.6
Lodgepole	Cheyenne	3,820	8	1903	14.1
Loup	Sherman	2,067	15	1909	23.6
Lynch	Boyd		14	1908	24.7
McCook	Redwillow	2,506	13	1907	20.8
McCool Junction	York	1,575	12	1909	28.9
Madison	Madison	1,585	15	1908	27.3
Madrid	Perkins	3,294	9	1901	14.6
Marquette	Hamilton	1,830	30	1909	27.0
Mason City	Custer	2,257	9	1909	27.5
Minden	Kearney	2,162	32	1909	31.3
Monroe	Platte	1,525	12	1909	28.4
Nebraska City	Otoe	961	31	1908	31.6
Nesbit	McPherson		7	1901	17.9
Norfolk	Madison	1,532	26	1909	28.8
North Loup	Valley	1,961	21	1909	24.7
North Platte	Lincoln	2,821	35	1909	18.0
Oakdale	Antelope	1,722	22	1909	26.2
Odell	Gage	1,278	15	1909	33.0
Omaha	Douglas	1,103	39	1909	30.7
Ord	Valley	2,062	15	1909	24.8
O'Neil	Holt	1,975	11	1901	23.2
Ough	Dundy		6	1896	15.7
Palmer	Merrick	1,796	18	1904	25.4
Palmyra	Otoe	1,142	14	1908	30.2
Pawnee City	Pawnee	1,175	14	1909	33.1
Plattsmouth	Cass	968	31	1904	31.6
Plymouth	Jefferson	1,419	5	1909	31.3
Purdum	Blaine		9	1909	23.2
Ravenna	Buffalo	2,028	32	1909	25.7
Redcloud	Webster	1,687	17	1909	25.6
Republican	Harlan	1,939	6	1900	21.8
Rulo	Richardson	842	5	1900	34.7
St. Libory	Howard	1,887	15	1909	29.3
St. Paul	do	1,813	15	1909	28.5
Santee	Knox		21	1909	25.0
Schuyler	Colfax	1,357	16	1909	28.8

BLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

NEBRASKA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
ttsbluff	Scottsbluff	4,662	3	1909	16.5
eca	Thomas	2,971	7	1900	14.8
vard	Seward	1,435	19	1909	31.2
ney	Cheyenne	4,090	[a] 17	1909	15.0
ringview	Keyapaha		16	1909	21.4
nton	Stanton	1,472	18	1909	27.5
atton	Hitchcock	2,804	12	1907	19.7
perior	Nuckolls	1,570	24	1908	27.2
racuse	Otoe	1,059	32	1909	30.8
kamah	Burt	1,060	19	1909	32.3
blerock	Pawnee	1,023	21	1909	31.5
cumseh	Johnson	1,114	31	1909	32.1
rlington	Otoe	1,224	17	1909	30.4
iversity Farm	Lancaster		24	1909	28.9
lentine	Cherry	2,859	21	1909	22.5
ahoo	Saunders	1,187	7	1909	35.3
akefield	Dixon	1,387	15	1909	28.9
anneta	Chase		11	1909	21.5
eepingwater	Cass	1,080	32	1909	30.5
estpoint	Cuming	1,313	23	1909	29.6
hitman	Grant	3,588	11	1901	13.3
ilber	Saline	1,325	15	1909	32.8
lsonville	Furnas	2,298	7	1901	21.6
innebago	Thurston		5	1905	30.0
isner	Cuming	1,380	14	1909	32.5
ymore	Gage	1,222	6	1903	30.1
rk	York	1,633	20	1909	29.1

NEVADA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
stin	Lander	6,594	15	1903	11.6
ttle Mountain	do	4,843	35	1905	7.1
elmont	Nye	8,132	13	1904	10.5
eowawe	Eureka	4,695	32	1902	6.4
mp Halleck	Elko	5,671	14	1886	15.0
mp McDermit	Humboldt	4,700	21	1888	13.2
ndelaria	Esmeralda	5,783	15	1904	5.0
rlin	Elko	4,897	30	1900	6.5
rson City	Ormsby	4,660	27	1906	12.3
dar Pass	Elko		7	1877	12.5
nnes Ranch	do	5,350	17	1904	10.0
lko	do	5.063	31	1901	6.9
ly	White Pine	6,000	18	1908	12.3
ernley	Lyon	4,200	2	1908	5.6
olconda	Humboldt	4,697	30	1908	6.0
lalleck	Elko	5.631	16	1908	9.4
larthorne	Esmeralda	4,569	17	1904	4.4
lot Springs	Churchill	4,072	20	1889	3.5
lumboldt	Humboldt	4,236	35	1906	5.5
on Point	do	4,375	8	1877	7.4
ewers Ranch	Washoe	5,500	21	1908	26.1
ovelock	Humboldt	3,977	10	1901	2.4
lartins Ranch	Douglas	4.830	6	1904	12.0
lill City	Humboldt	4,225	17	1905	5.2
tego	Elko		8	1886	8.0
alisade	Eureka	4.821	21	1902	8.0
almetto	Esmeralda	6.780	18	1907	14.6
ioche	Lincoln	6.110	9	1890	11.2
otts	Nye	6,990	16	1908	7.5
eno	Washoe	4.532	38	1908	10.4
ecoma	Elko	4.812	31	1908	6.5
onopah	Nye	6,090	2	1908	10.2
oano	Elko	5,975	33	1902	8.3
ybo	Nye	6.500	10	1901	9.5
erdi	Washoe	4.895	12	1901	15.8
Wadsworth	Washoe	4.077	32	1903	4.3
Wells	Elko	5.623	30	1901	9.1
Winnemucca	Humboldt	4.432	30	1908	8.4

[a] Except the months of January and February.

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

NEW MEXICO.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Agricultural College	Dona Ana	3,863	22	1908	9.1
Alamogordo	Otero	4,338	8	1908	10.9
Albert	Union	4,700	19	1908	16.3
Albuquerque	Bernalillo	5,200	33	1908	7.9
Alma	Socorro	5,500	11	1905	14.1
Aztec	San Juan	5,590	6	1900	8.4
Bell Ranch	San Miguel	4,500	10	1908	15.8
Bernalillo	Sandoval	5,200	5	1899	8.2
Bloomfield	San Juan	5,500	12	1908	8.5
Bluewater	Valencia	6,200	7	1902	9.5
Cambray	Luna	4,215	9	1908	9.4
Camp Burgwin	Taos	7,900	6	1860	8.6
Carlsbad	Eddy	3,120	14	1908	14.6
Chama	Rio Arriba	7,848	12	1908	23.3
Cliff	Grant	4,470	11	1908	14.9
Cloudcroft	Otero	8,650	7	1908	25.1
Deming	Luna	4,333	26	1908	8.9
Dorsey	Colfax	6,000	6	1908	15.4
Eagle Rock Ranch	Union	6,000	10	1907	18.3
East Las Vegas	San Miguel	6,450	14	1901	19.4
Eddy	Eddy	3,122	5	1898	12.8
Elk	Chaves	....	11	1908	21.6
Engle	Sierra	4,750	7	1901	10.4
Espanola	Rio Arriba	5,590	12	1908	9.5
Folsom	Union	6,000	5	1902	15.8
Fort Bayard	Grant	6,152	34	1908	14.6
Fort Craig	Socorro	4,619	24	1884	10.8
Fort Fillmore	Dona Ana	3,937	10	1861	8.0
Fort Selden	....do	3,937	16	1890	8.6
Fort Stanton	Lincoln	6,231	30	1908	17.3
Fort Thorn	Dona Ana	4,500	6	1858	14.5
Fort Union	Mora	6,835	49	1908	19.4
Fort Wingate	McKinley	6,997	46	1908	14.3
Fruitland	San Juan	4,800	15	1908	5.1
Gage	Luna	4,486	10	1908	8.5
Galisteo	Santa Fe	6,074	8	1901	13.3
Gallinas Springs	San Miguel	5,272	18	1902	15.6
Gila	Grant	4,040	5	1899	14.6
Hillsboro	Sierra	5,224	14	1908	13.1
Las Cruces	Dona Ana	3,500	9	1897	8.8
Las Vegas	San Miguel	6,384	22	1908	19.3
Lava	Socorro	4,703	6	1890	10.8
Lordsburg	Grant	4,245	27	1908	8.5
Los Lunas	Valencia	4,900	18	1908	10.3
Lower Penasco	Chaves	5,250	5	1900	17.6
Lyons Ranch	Grant	4,040	6	1900	14.6
Mesilla Park	Dona Ana	3,868	21	1907	8.9
Mountainair	Torrance	6,547	7	1908	16.9
Puerto de Luna	Guadalupe	5,350	6	1898	17.3
Raton	Colfax	6,622	10	1904	12.7
Rincon	Dona Ana	4,031	11	1908	7.6
Roswell	Chaves	3,578	14	1908	15.8
San Marcial	Socorro	4,554	3	1899	8.1
San Rafael	Valencia	6,509	12	1908	11.9
Santa Fe	Santa Fe	7,013	36	1908	14.3
Shattucks	Eddy	6,000	3	1899	22.4
Socorro	Socorro	4,600	17	1908	10.7
Springer	Colfax	5,857	17	1908	13.[illegible]
Strauss	Dona Ana	4,080	8	1907	10.[illegible]
Taos	Taos	6,983	14	1908	12.[illegible]
White Oaks	Lincoln	6,470	4	1900	17.[illegible]
Winsors	San Miguel	8,200	13	1908	22.[illegible]

NORTH DAKOTA.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
Amenia	Cass	954	12	1908	21.[illegible]
Ashley	McIntosh	2,007	13	1906	18.[illegible]
Berlin	Lamoure	1,470	14	1905	20.[illegible]
Berthold Agency	McLean	2,062	13	1908	16.[illegible]
Bismarck	Burleigh	1,674	34	1908	17.[illegible]
Bottineau	Bottineau	1,638	14	1908	15.[illegible]
Buxton	Traill	930	5	1902	16.[illegible]
Cando	Towner	1,488	7	1907	17.[illegible]

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

NORTH DAKOTA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Churchs Ferry	Ramsey	1,458	10	1904	23.0
Coal Harbor	McLean	1,901	13	1908	16.9
Devils Lake	Ramsey	1,482	4	1908	20.2
Dickinson	Stark	2,543	17	1908	15.0
Donnybrook	Ward	1,760	9	1907	12.3
Dunseith	Rolette	....	12	1908	14.9
Edgeley	Lamoure	1,468	8	1908	19.5
Ellendale	Dickey	1,449	12	1904	16.3
Fargo	Cass	903	15	1906	19.4
Forman	Sargent	1,249	12	1905	19.4
Fort Yates	Morton	1,670	26	1907	16.3
Fullerton	Dickey	1,439	11	1908	22.1
Gallatin	Griggs	....	9	1902	17.7
Glenullin	Morton	2,070	10	1905	13.3
Grafton	Walsh	827	16	1906	16.8
Hamilton	Pembina	824	9	1905	22.0
Jamestown	Stutsman	1,390	22	1908	20.0
Larimore	Grand Forks	1,134	11	1905	17.2
McKinney	Ward	1,640	15	1908	15.4
Mayville	Traill	975	13	1908	21.1
Medora	Billings	2,225	13	1908	13.2
Melville	Foster	1,590	12	1908	16.0
Milton	Cavalier	1,586	10	1902	16.8
Minot	Ward	1,557	11	1908	16.5
Minto	Walsh	820	16	1908	18.8
Minnewaukon	Benson	1,459	7	1904	17.6
Moorhead, Minn	Clay	940	29	1908	24.9
Napoleon	Logan	1,955	18	1908	19.1
New England	Hettinger	2,400	13	1908	12.7
Oakdale	Dunn	....	12	1906	16.1
Pembina	Pembina	789	11	1908	19.8
Portal	Ward	1,954	13	1906	14.2
Power	Richland	1,020	17	1908	20.6
Steele	Kidder	1,857	13	1907	15.7
University	Grand Forks	830	17	1908	20.5
Wahpeton	Richland	962	13	1904	27.3
Williston	Williams	1,875	29	1908	15.1
Willow City	Bottineau	1,471	15	1907	14.5
Woodbridge	Cavalier	....	10	1902	22.7

OKLAHOMA.

Arapaho	Custer	1,575	15	1908	29.0
Ardmore	Carter	872	4	1908	38.9
Beaver	Beaver	2,500	9	1908	19.7
Blackburn	Pawnee	800	8	1908	46.5
Burnett	Pottawatomie	1,200	11	1902	33.0
Chandler	Lincoln	865	7	1908	38.5
Chickasha	Grady	1,091	9	1908	31.9
Cloud Chief	Washita	1,400	7	1908	32.0
Dacoma	Woods	1,337	11	1908	28.7
Durant	Bryan	643	7	1908	43.3
Enid	Garfield	1,269	10	1908	32.5
Fairland	Ottawa	839	9	1908	42.2
Fort Reno	Canadian	1,400	21	1908	30.4
Fort Sill	Comanche	1,200	37	1908	30.9
Fort Smith (Ark.)	Sebastian	457	28	1908	44.7
Gage	Ellis	2,136	6	1908	28.2
Guthrie	Logan	1,000	16	1908	33.2
Harrington	Roger Mills	....	5	1908	30.7
Hartshorne	Pittsburg	700	10	1908	44.3
Healdton	Carter	900	18	1908	37.1
Hennessey	Kingfisher	1,166	12	1908	31.5
Hobart	Kiowa	1,396	6	1908	31.7
Holdenville	Hughes	900	8	1908	43.2
Hopeton	Woods	....	2	1899	29.4
Jefferson	Grant	1,062	15	1908	30.4
Jenkins	Woods	1,337	8	1905	27.0
Kenton	Cimarron	4,000	8	1908	15.5
Kingfisher	Kingfisher	1,046	11	1908	35.8
Lehigh	Coal	593	8	1900	34.9
McAlester	Pittsburg	698	13	1908	46.0
McComb	Pottawatomie	1,200	17	1908	34.0

Table VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

OKLAHOMA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Mangum	Greer	1,585	17	1908	25.2
Marlow	Stephens	1,292	8	1908	35.1
Meeker	Lincoln	1,030	15	1906	34.6
Muskogee	Muskogee	614	10	1908	38.0
Newkirk	Kay	1,149	11	1908	36.4
Norman	Cleveland	1,180	14	1908	33.6
Oklahoma	Oklahoma	1,247	18	1908	32.8
Okmulgee	Okmulgee	752	7	1908	41.2
Pawhuska	Osage	918	10	1908	42.3
Perry	Noble	920	9	1908	36.1
Prudence	Major		6	1900	32.9
Ravia	Johnston	796	6	1908	42.1
Sac and Fox Agency	Lincoln	900	16	1908	34.5
Shawnee	Pottawatomie	1,041	7	1906	38.9
South McAlester	Choctaw Nation	698	13	1905	45.3
Stillwater	Payne	880	16	1908	35.2
Temple	Comanche	925	6	1908	34.5
Tulsa (1)	Tulsa	700	20	1908	35.9
Tahlequah	Cherokee	790	9	1902	42.5
Taloga	Dewey		4	1903	24.4
Vinita	Craig	698	6	1908	43.3
Vittum	Logan	940	8	1900	30.0
Wagoner	Wagoner	588	12	1908	39.0
Waukomis	Garfield	1,258	12	1906	31.6
Weatherford	Custer	1,639	8	1908	26.9
Webbers Falls	Muskogee	479	11	1908	40.7
Whiteagle	Kay	945	6	1908	41.9
Winnview	Blaine		7	1899	28.1
Woodward	Woodward	2,300	6	1901	15.2

OREGON.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
Albany	Linn	214	32	1908	44.7
Alpha	Lane	250	7	1906	87.1
Arlington	Gilliam	855	14	1904	9.1
Ashland	Jackson	1,940	21	1908	20.1
Astoria	Clatsop	11	49	1908	74.5
Aurora	Marion	144	10	1901	46.7
Baker City	Baker	3,464	20	1908	12.8
Bandon	Coos	55	27	1899	60.6
Bay City	Tillamook	225	14	1908	105.3
Bend	Crook		6	1907	13.7
Beulah	Malheur	3,269	14	1905	10.7
Blalock	Gilliam	237	10	1908	10.4
Brownsville	Linn	346	11	1902	36.9
Buckhorn Farm	Josephine	1,300	10	1908	70.3
Bull Run	Clackamas	719	10	1907	76.3
Burns	Harney	4,157	19	1908	10.5
Cascade Locks	Hood River	100	30	1908	79.0
Comstock	Douglas	473	11	1902	36.8
Coquille River Light-House	Coos	13	10	1907	57.5
Corvallis	Benton	319	20	1908	41.8
Dayville	Grant	1,500	14	1908	12.5
Doraville	Columbia	600	7	1906	40.4
Drain	Douglas	300	6	1908	47.8
Ella	Morrow		11	1909	9.0
Eugene	Lane	449	18	1908	37.9
Fairview	Coos	142	11	1908	70.8
Falls City	Polk	355	11	1907	82.7
Forest Grove	Washington	220	17	1906	49.0
Gardiner	Douglas	72	20	1908	79.3
Glenora	Tillamook	575	17	1908	117.6
Gold Beach	Curry	40	6	1908	88.5
Government Camp	Clackamas	3,580	11	1906	89.3
Grants Pass	Josephine	956	20	1908	44.8
Happy Valley	Harney	4,200	10	1899	13.2
Hare	Curry	1,342	10	1901	99.7
Headworks	Clackamas	719	10	1908	82.2
Heppner	Morrow	1,960	20	1908	15.5
Hood River	Hood River	243	24	1907	36.4
Huntington	Baker	2,110	7	1907	12.9
Irvington	Multnomah	75	12	1899	32.5
Jacksonville	Jackson	1,640	20	1908	27.2

ABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

OREGON—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
oseph	Wallowa	4,400	19	1908	18.2
unction City	Lane	353	11	1902	33.6
lamath Falls	Klamath	4,250	14	1908	14.0
afayette	Yamhill	182	11	1902	42.9
a Grande	Union	2,784	21	1908	19.5
akeview	Lake	4,825	23	1907	16.9
anglois	Curry	250	9	1899	101.8
one Rock	Gilliam	3,114	18	1905	14.6
cKenzie Bridge	Lane	1,400	8	1908	72.2
cMinnville	Yamhill	180	21	1908	47.8
arshfield	Coos	12	6	1907	66.7
erlin	Josephine	934	10	1901	34.9
iramonte Farm	Clackamas	195	17	1908	43.5
onmouth	Polk	221	11	1902	39.6
onroe	Benton	350	11	1908	39.9
ount Angel	Marion	485	23	1908	46.0
ehalem	Tillamook	10	13	1907	111.9
ewberg	Yamhill	193	9	1902	47.9
ew Bridge	Baker	1,900	9	1900	9.6
ewport	Lincoln	69	19	1908	56.3
endleton	Umatilla	1,272	19	1908	14.2
lacer	Josephine	....	4	1901	39.2
ompeii	Clackamas	3,580	13	1908	85.4
ortland	Multnomah	57	37	1908	46.0
rineville	Crook	3,000	11	1907	8.8
iddle	Douglas	733	11	1902	29.8
iverside	Malheur	....	5	1901	8.7
oseburg	Douglas	523	32	1908	34.0
alem	Marion	120	17	1908	40.5
heridan	Yamhill	207	11	1902	43.0
ilver Lake	Lake	4,700	12	1907	10.4
ilverton	Marion	255	11	1902	45.2
iskiyou	Jackson	4,135	11	1902	29.2
parta	Baker	4,150	15	1906	23.9
pringfield	Lane	476	9	1900	39.1
afford	Clackamas	....	13	1908	32.4
he Dalles	Wasco	112	34	1908	14.2
oledo	Lincoln	50	19	1908	79.4
matilla	Umatilla	340	22	1908	8.6
ale	Malheur	2,450	17	1908	10.2
ernonia	Columbia	1,238	11	1899	62.1
allowa	Wallowa	2,935	7	1909	17.2
armsprings	Crook	1,600	6	1907	11.5
est Fork	Douglas	1,046	11	1901	41.2
eston	Umatilla	1,800	19	1908	24.5
illiams	Josephine	1,368	15	1906	33.5

SOUTH DAKOTA.

berdeen	Brown	1,300	19	1908	26.9
cademy	Charles Mix	....	10	1908	22.5
lexandria	Hanson	1,352	22	1908	24.6
rmour	Douglas	1,521	14	1908	24.6
shcroft	Harding	3,192	17	1908	14.0
owdle	Edmunds	1,995	14	1908	19.3
rookings	Brookings	1,636	20	1908	20.0
anton	Lincoln	1,248	12	1906	26.3
enterville	Turner	1,229	12	1908	27.1
hamberlain	Brule	1,363	12	1908	17.9
handler (Academy)	Charles Mix	....	1	1899	19.8
herry Creek	Armstrong	....	13	1907	14.0
lark	Clark	1,779	17	1908	22.6
e Smet	Kingsbury	1,726	16	1907	21.7
lla Point	Union	1,127	8	1906	29.0
armingdale	Pennington	3,000	11	1905	13.9
aulkton	Faulk	1,595	14	1908	19.5
landreau	Moody	1,565	19	1908	24.5
orestburg	Sanborn	1,231	16	1907	21.2
orest City	Potter	....	6	1899	15.7
ort Meade	Meade	3,624	28	1907	19.8
annvalley	Buffalo	....	8	1905	20.7
ary	Deuel	1,484	9	1900	22.6
rand River School	Corson	....	2	1901	14.5

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

SOUTH DAKOTA—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Greenwood	Charles Mix		15	1908	23.7
Harney	Pennington	5,000	9	1898	18.4
Hartman	Minnehaha	1,474	4	1901	23.9
Highmore	Hyde	1,890	16	1908	17.4
Hotch City	Lyman		13	1905	14.5
Hot Springs	Fall River	3,447	4	1900	12.5
Howard	Miner	1,564	17	1908	21.5
Howell	Hand		7	1908	18.2
Huron	Beadle	1,306	27	1908	21.1
Ipswich	Edmunds	1,530	11	1907	22.6
Kidder	Marshall	1,295	5	1908	22.4
Kimball	Brule	1,788	23	1908	19.3
La Delle	Spink	1,400	12	1908	24.2
Leola	McPherson	1,587	6	1905	19.7
Marion	Turner	1,447	8	1908	26.5
Melette	Spink	1,300	14	1908	20.3
Menno	Hutchinson	1,325	12	1908	24.4
Milbank	Grant	1,148	18	1908	22.4
Mitchell	Davison	1,312	15	1908	23.2
Mound City	Campbell		1	1901	24.8
Nowlin	Stanley		4	1898	9.7
Oelrichs	Fall River	3,339	18	1908	19.4
Parker	Turner	1,348	9	1900	22.9
Pierre	Hughes	1,572	17	1908	16.6
Pine Ridge	Shannon		1	1901	13.1
Plankinton	Aurora	1,528	15	1908	21.1
Ramsey	McCook	1,474	8	1905	23.1
Rapid City	Pennington	3,251	21	1908	18.7
Redfield	Spink	1,295	11	1908	20.1
Rosebud	Meyer	2,600	15	1908	18.3
St. Lawrence	Hand	1,580	4	1901	18.7
Silver City	Pennington	5,000	9	1903	20.6
Sioux Falls	Minnehaha	1,400	18	1908	25.1
Sisseton Agency	Roberts		5	1904	25.5
Spearfish	Lawrence	3,647	19	1908	22.6
Stephan	Hyde	1,840	5	1908	18.1
Tyndall	Bonhomme	1,418	14	1906	23.6
Vermillion	Clay	1,420	8	1908	26.7
Watertown	Codington	1,735	15	1908	22.6
Waubay	Day	1,813	3	1901	21.3
Wentworth	Lake		16	1908	22.6
Wessington Springs	Jerauld	1,335	8	1899	20.2
White Swan	Charles Mix		5	1898	20.9
Wolsey	Beadle	1,353	15	1907	20.1
Yankton	Yankton	1,234	35	1908	25.4

TEXAS.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
Abilene	Taylor	1,738	24	1908	24.7
Albany	Shackelford	1,429	15	1908	27.2
Alvin	Brazoria	49	8	1905	52.1
Amarillo	Potter	3,676	17	1908	22.6
Arthur City	Lamar	590	15	1905	36.1
Austin	Travis	650	23	1908	34.4
Ballinger	Runnels	1,637	14	1908	25.0
Beaumont	Jefferson	29	12	1908	41.9
Beeville	Bee	225	13	1908	29.6
Big Springs	Howard	2,396	7	1908	20.4
Blanco	Blanco	1,350	12	1907	29.6
Boerne	Kendall	1,412	16	1907	29.8
Bonham	Fannin	566	6	1908	47.6
Booth	Fort Bend	81	8	1908	43.3
Bowie	Montague	1,113	9	1908	27.9
Brazoria	Brazoria	25	18	1908	47.5
Brenham	Washington	350	20	1908	41.5
Brighton	Nueces	12	13	1908	23.3
Brownsville	Cameron	38	20	1908	27.1
Brownwood	Brown	1,342	12	1903	27.5
Burnet	Burnet	1,295	15	1904	28.3
Childress	Childress	1,869	15	1907	21.4
Coleman	Coleman	1,710	15	1908	27.6
College Station	Brazos	360	19	1907	38.4
Colorado	Mitchell	2,066	18	1908	22.0

BLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

TEXAS—Continued.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
umbia	Brazoria	34	20	1908	43.8
pus Christi	Nueces	20	22	1908	27.2
sicana	Navarro	495	23	1908	37.9
ro	Dewitt	177	20	1908	34.1
las	Dallas	466	10	1908	35.5
nevang	Wharton	145	13	1908	45.9
Rio	Valverde	952	3	1908	26.8
lville	Cherokee	575	7	1904	41.6
blin	Erath	1,466	14	1908	29.2
val	Travis	820	20	1908	30.8
gle Pass	Maverick	800	20	1908	21.6
Paso	El Paso	3,762	30	1908	9.8
telle	Dallas	614	11	1904	32.1
restburg	Montague	....	6	1903	33.9
rt Brown	Cameron	57	16	1905	20.6
rt Clark	Kinney	1,050	22	1908	22.7
rt Davis	Jeff Davis	5,000	10	1905	14.0
rt McIntosh	Webb	460	22	1907	17.8
rt Ringgold	Starr	230	20	1905	16.8
rt Stockton	Pecos	3,050	26	1908	15.9
rt Worth	Tarrant	670	13	1908	26.9
edericksburg	Gillespie	1,742	20	1908	28.4
inesville	Cooke	738	20	1908	37.3
lveston	Galveston	69	38	1908	47.1
apevine	Tarrant	670	19	1908	36.3
orgetown	Williamson	750	14	1908	35.5
reenville	Hunt	550	9	1908	42.1
ale Center	Hale	3,000	12	1905	21.2
alletsville	Lavaca	235	18	1908	33.2
askell	Haskell	1,553	14	1905	21.6
earne	Robertson	305	17	1905	34.1
enrietta	Clay	915	11	1905	26.9
ewitt	McLennan	664	15	1908	36.7
ondo City	Medina	901	13	1908	28.1
ouston	Harris	53	20	1908	48.4
untsville	Walker	400	21	1908	45.2
aufman	Kaufman	448	7	1908	44.4
ent	El Paso	....	12	1903	12.2
errville	Kerr	1,650	14	1908	29.8
opperl	Bosque	576	18	1908	33.5
ampasas	Lampasas	1,026	18	1908	29.5
a Para	Live Oak	....	....	1903	21.9
lano	Llano	1,040	17	1907	22.4
ongview	Gregg	336	20	1908	47.1
uling	Caldwell	418	20	1908	29.2
cKinney	Collin	612	6	1904	32.8
enardville	Menard	1,900	16	1904	21.9
ount Blanco	Crosby	2,750	23	1908	21.3
acogdoches	Nacogdoches	271	10	1908	51.2
New Braunfels	Comal	720	18	1906	29.4
Palestine	Anderson	510	27	1908	43.0
Panter	Hood	1,000	17	1905	32.5
Paris	Lamar	592	20	1908	34.6
Port Lavaca	Calhoun	20	8	1908	41.1
Rhineland	Knox	....	11	1906	23.4
Rock Island	Colorado	254	8	1906	41.3
Runge	Karnes	308	14	1908	30.2
San Antonio (1)	Bexar	701	24	1908	26.8
San Marcos	Hays	588	16	1908	31.3
San Saba	San Saba	1,712	5	1908	23.4
Santa Gertrudes	Nueces	....	7	1908	24.1
Sherman	Grayson	728	15	1907	34.2
Sonora	Sutton	2,200	6	1908	23.6
Sugarland	Fort Bend	79	11	1908	44.2
Sulphur Springs	Hopkins	530	16	1907	39.0
Taylor	Williamson	583	8	1908	35.5
Temple (1)	Bell	630	15	1908	34.9
Texarkana	Bowie	295	10	1905	37.2
Tulia	Swisher	3,501	11	1908	27.0
Tyler	Smith	531	17	1905	38.4
Victoria	Victoria	187	17	1908	36.5
Waco	McLennan	424	20	1908	36.9
Waxahachie	Ellis	556	13	1908	35.4
Weatherford	Parker	864	20	1908	31.2
Wichita Falls	Wichita	958	14	1904	28.8

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

UTAH.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Alpine	Utah	4,900	9	1905	16.4
Aneth	San Juan	4,800	5	1905	6.7
Annabelle (near)	Sevier	5,250	4	1909	13.7
Beaver	Beaver	6,000	6	1909	11.6
Black Rock	Millard	4,872	4	1904	8.4
Blue Creek	Boxelder	4,387	26	1903	8.4
Brigham	....do	4,379	5	1899	15.8
Camp Douglas	Salt Lake	4,800	22	1890	17.4
Castle Dale	Emery	5,500	10	1909	7.4
Castle Rock	Summit	6,244	6	1909	16.1
Coalville	....do	5,630	8	1882	13.7
Corinne	Boxelder	4,240	39	1909	12.3
Deseret	Millard	4,541	15	1909	7.9
Emery	Emery	6,260	8	1908	4.1
Escalante	Garfield	5,700	9	1909	11.2
Farmington	Davis	4,267	9	1909	21.9
Fillmore	Millard	5,100	19	1909	14.1
Fort Duchesne	Uinta	5,000	21	1909	7.1
Frisco	Beaver	7,318	15	1909	8.1
Garrison	Millard	....	6	1909	6.6
Giles	Wayne	4,000	10	1905	5.1
Government Creek	Tooele	5,277	9	1909	14.0
Grantville (near)	....do	....	4	1909	13.0
Grayson	San Juan	5,750	5	1909	20.1
Green River	Emery	4,080	11	1908	4.7
Grover (near)	Wayne	5,800	8	1903	6.8
Heber	Wasatch	5,606	16	1909	17.0
Henefer	Summit	5,301	10	1909	13.2
Hite	Garfield	3,000	10	1909	6.7
Huntsville	Weber	5,100	14	1909	20.0
Kelton	Boxelder	4,230	31	1909	6.2
Levan	Juab	5,010	19	1909	16.0
Loa	Wayne	7,000	17	1909	6.0
Logan	Cache	4,507	18	1909	15.3
Manti	Sanpete	5,575	15	1909	13.0
Marion	Summit	6,750	5	1909	21.0
Marysvale (near)	Piute	6,180	10	1909	11.0
Meadowville	Rich	6,200	10	1907	14.3
Millville	Cache	4,848	14	1909	15.0
Minersville	Beaver	5,070	10	1907	9.3
Moab	Grand	4,000	20	1909	8.3
Modena	Iron	5,479	9	1909	10.3
Morgan	Morgan	5,080	6	1909	20.3
Mount Nebo	Utah	4,650	8	1909	18.0
Mount Pleasant	Sanpete	5,859	12	1904	12.0
Nephi	Juab	6,059	6	1909	13.3
Nephi (near)	....do	....	....	1909	15.1
Ogden (1)	Weber	4,310	8	1909	21.
Ogden (2)	....do	4,310	38	1908	13.
Pahreah	Kane	4,000	5	1899	9.
Park City	Summit	7,800	5	1901	19.
Parowan	Iron	5,970	18	1909	12.
Payson	Utah	4,637	6	1909	20.
Pinto	Washington	5,907	12	1909	15.
Promontory	Boxelder	....	21	1890	7.
Provo	Utah	4,532	17	1909	13.
Ranch	Kane	6,700	8	1909	23.
Randolph	Rich	6,442	6	1909	11.
Richfield	Sevier	5,350	19	1909	7.
St. George	Washington	2,880	22	1908	6.
Salt Lake City	Salt Lake	4,366	35	1909	16.
Scipio	Millard	5,260	14	1909	14.
Snowville	Boxelder	4,360	18	1908	10.
Soldiers Summit	Utah	7,474	12	1904	14.
Terrace	Boxelder	4,550	34	1903	4.
Thistle	Utah	5,075	16	1908	12.
Tooele	Tooele	4,900	13	1909	15.
Tropic	Garfield	7,000	12	1909	10.
Vernal (near)	Uinta	5,050	14	1909	8.
Woodruff	Rich	6,500	10	1907	8.

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

WASHINGTON.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Aberdeen	Chehalis	162	17	1907	86.9
Anacortes	Skagit	60	15	1908	28.0
Ashford	Pierce	1,775	12	1906	71.8
Bellingham	Whatcom	60	14	1908	31.5
Blaine	do	53	12	1908	42.8
Bremerton	Kitsap		10	1908	43.9
Brinnon	Jefferson	80	8	1906	75.5
Cedonia	Stevens	3,000	12	1905	20.4
Centralia	Lewis	212	16	1908	46.6
Cheney	Spokane	2,351	10	1908	17.2
Clearwater	Jefferson	135	12	1907	127.6
Cle Elum	Kittitas	1,930	10	1908	26.7
Colfax	Whitman	2,300	20	1908	23.0
Colville	Stevens	1,635	9	1908	17.8
Conconully	Okanogan	2,300	9	1908	16.7
Coupeville	Island	150	13	1908	21.7
Crescent	Lincoln	2,250	8	1907	17.8
Cusick	Stevens	2,050	7	1905	23.9
Dayton	Columbia	1,700	23	1908	23.2
East Sound	San Juan	500	14	1908	31.8
Ellensburg	Kittitas	1,571	21	1908	9.9
Fort Canby	Pacific	179	30	1898	54.1
Fort Simcoe	Yakima		11	1898	9.3
Fort Spokane	Lincoln	1,400	15	1898	13.9
Grand Mound	Thurston	162	9	1903	52.6
Granite Falls	Snohomish	397	6	1905	60.3
Hooper	Whitman	1,083	5	1903	12.4
Hunters	Stevens		5	1898	20.4
Kennewick	Benton	367	12	1906	6.7
La Center	Clarke	250	12	1908	55.0
Lakeside	Chelan	1,116	18	1908	12.7
Lapush	Clallam	15	5	1898	85.8
Lind	Adams	1,700	9	1905	11.8
Loomis	Okanogan	1,200	9	1905	13.7
Lyle	Klickitat	600	15	1907	26.3
Madrone	Kitsap	75	21	1898	44.5
Mayfield	Lewis	300	9	1902	65.9
Mottingers Ranch	Benton	307	9	1908	9.3
Mount Pleasant	Skamania	650	9	1908	55.5
Moxee (North Yakima)	Yakima	1,000	17	1908	8.9
Neah Bay	Clallam	50	20	1901	116.7
North Head	Pacific	211	7	1908	45.8
North Port	Stevens	1,950	10	1908	20.8
Olga	San Juan	50	19	1908	30.3
Olympia	Thurston	200	31	1908	55.2
Pasco	Franklin	360	1	1901	6.5
Pomeroy	Garfield	1,500	15	1908	19.0
Port Crescent	Clallam	259	14	1908	42.2
Port Townsend	Jefferson	80	19	1908	20.6
Pullman (Agricultural College)	Whitman	2,550	17	1908	22.4
Republic	Ferry	2,628	9	1908	18.0
Ritzville	Adams	1,825	10	1909	9.8
Rosalia	Whitman	2.375	16	1907	20.2
Seattle	King	123	18	1908	36.7
Sedro-Woolley	Skagit	38	12	1908	46.8
Silvana	Snohomish	35	10	1903	36.4
Snohomish	do	50	14	1907	45.2
Snoqualmie Falls	King	667	10	1908	59.5
South Bend	Pacific	16	14	1908	90.5
South Ellensburg	Kittitas	1,570	11	1904	9.3
Spokane	Spokane	1,943	28	1908	18.9
Sprague	Lincoln	1,908	6	1904	15.1
Sunnyside	Yakima	764	12	1906	6.6
Tacoma	Pierce	213	23	1908	45.4
Tatoosh	Clallam	86	23	1908	88.8
Twin	do	6	2	1900	66.5
Union City	Mason	10	14	1906	83.4
Vancouver	Clarke	100	34	1908	38.7
Vashon Island	King	110	20	1908	42.0
Walla Walla	Wallawalla	1,000	23	1908	17.7
Waterville	Douglas	2,624	18	1907	13.2
Wenatchee (near)	Chelan	1,169	10	1908	15.5
Whatcom	Whatcom	60	9	1903	31.9
Wilbur	Lincoln	2,203	10	1908	15

TABLE VI.—*Normal precipitation of stations in the western United States grouped according to States*—Continued.

WYOMING.

Station.	County.	Elevation.	Number of years recorded.	Record ended—	Normal precipitation.
		Feet.			*Inches.*
Afton	Uinta	6,200	4	1906	18.3
Alcova	Natrona	5,366	6	1904	9.4
Barnum	Johnson	5,500	8	1907	12.0
Basin	Big Horn	3,862	11	1909	5.8
Bedford	Uinta	5,906	9	1907	18.4
Border	.....do	6,085	8	1909	14.1
Buffalo	Johnson	4,635	16	1907	10.9
Centennial	Albany	8,700	4	1902	16.9
Cheyenne	Laramie	6,088	39	1909	13.6
Chugwater	.....do	5,282	9	1909	16.0
Clark	Park	4,320	3	1907	11.6
Daniel	Uinta	6,740	11	1909	11.6
Elk Mountain	Carbon	....	3	1907	18.6
Evanston	Uinta	6,860	14	1909	14.0
Fort Laramie	Laramie	4,270	33	1909	12.2
Fort Washakie	Fremont	5,462	22	1908	12.3
Fourbear	Big Horn	6,500	11	1903	11.3
Granite Canon	Laramie	7,373	3	1907	16.9
Granite Springs Reservation	.....do	....	2	1907	16.8
Green River	Sweetwater	6,083	3	1907	8.5
Griggs	Johnson	4,700	7	1907	14.4
Iron Mountain	Laramie	6,605	4	1902	11.6
Kaycee	Johnson	....	8	1908	14.3
Kirtley	Converse	....	4	1907	16.3
Lander	Fremont	5,372	18	1909	13.9
Laramie	Albany	7,188	19	1909	10.2
Leo	Carbon	6,878	9	1909	9.8
Lolabama Ranch	Park	7,052	5	1906	11.8
Lusk	Converse	5,007	20	1909	14.0
Moorcroft	Crook	4,211	5	1907	15.1
Moore	Albany	6,000	7	1907	14.8
Pathfinder	Natrona	5,735	4	1909	9.7
Phillips	Laramie	4,900	6	1908	17.4
Pine Bluff	.....do	5,038	9	1908	15.0
Rawlins	Carbon	6,744	8	1907	11.3
Rock Springs	Sweetwater	6,500	8	1902	6.9
Saratoga	Carbon	7,300	11	1907	13.5
Sheridan (1)	Sheridan	3,790	15	1909	15.0
Sheridan (2)	.....do	3,738	15	1909	15.0
Soldiers' Home	Johnson	4,635	18	1909	11.3
South Pass City	Fremont	7,873	6	1905	14.8
Thayne	Uinta	5,900	7	1905	14.8
Thermopolis	Fremont	4,700	5	1903	12.1
Wells	Uinta	7,785	3	1906	17.7
Wheatland	Laramie	4,741	12	1906	13.1
Yellowstone Park	National Park	6,200	22	1909	18.8

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 189.

B. T. GALLOWAY, *Chief of Bureau.*

E SOURCE OF THE DRUG DIOSCOREA, WITH A CONSIDERATION OF THE DIOSCOREÆ FOUND IN THE UNITED STATES.

BY

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DRUG-PLANT, POISONOUS-PLANT, PHYSIOLOGICAL, AND FERMENTATION INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., July 20, 1910.

SIR: I have the honor to transmit herewith, and to recommend for iblication as Bulletin No. 189 of the series of this Bureau, a manuript entitled "The Source of the Drug Dioscorea, with a Consideraon of the Dioscoreæ found in the United States," prepared by Mr. arley Harris Bartlett, Chemical Biologist in the Office of Druglant Investigations, and submitted for publication by Dr. Rodney . True, Physiologist in Charge.

For many years there has been more or less confusion among crudeug dealers in regard to what plant should be considered the true edicinal "Dioscorea." Although there is little real evidence that ur native species of Dioscorea differ much in their medicinal quales, some authors have expressed a marked preference for a rhizome hich is now very rare in the trade. It is here shown that there is etter historical precedent for the use of the rhizome now handled by rude-drug dealers than for the form which of late has been preferred.

In carrying out this investigation Mr. Bartlett has found it necesary to consult much material located in many herbaria, collections, nd museums. He was assisted very materially by drug specimens or nformation furnished by Mr. Floyd Cole (Trade, Tenn.), Mr. H. E. Ellis (St. Petersburg, Fla.), J. Q. McGuire & Co. (Asheville, N. C.), Mr. Joseph Powell (Bristol, Tenn), Mr. R. W. Proctor (Cincinnati, hio), and Vannoy & McNeill (North Wilkesboro, N. C.). To the ollowing persons he is indebted for the use of herbarium specimens or otes on geographic distribution: Mr. W. H. Aiken (Lloyd Library), Prof. S. M. Bain (University of Tennessee), Mr. H. W. Barre (South Carolina Agricultural Experiment Station), Mr. C. D. Beadle (Biltmore Herbarium), Prof. W. J. Beal (Michigan State Agricultural College), Mr. Stewardson Brown (Philadelphia Academy of Natural Sciences), Prof. W. A. Buckhout (Pennsylvania State College), Mr. George H. Chapman (Massachusetts Agricultural Experiment Station), Prof. Mel. T. Cook (Agricultural Experiment Station, Delaware College), Mr. C. C. Deam (Indiana State Board of Forestry), Prof. R. J. H. De Loach (University of Georgia), Prof. R. H. Denniston (University of Wisconsin), Mr. H. S. Fawcett (University of Florida), Prof. E. M. Freeman (University of Minnesota), Prof. H. Garman (University of Kentucky), Dr. H. A. Gleason (University of Illinois), Prof. F. D. Heald (University of Texas), Mr. O. E. Jennings (Carnegie Museum), Prof. F. E. Lloyd (Alabama Polytechnic Institute), Mr. J. M. Macoun (Geological Survey of Canada), Prof. L. H. Pammel (Iowa Agricultural Experiment Station), Mr. J. T. Pennypacker (Delaware Natural History Society), Prof. G. M. Reed (University of Missouri), Prof. B. L. Robinson (Gray Herbarium), Mr. A. D. Selby (Ohio Experiment Station), Prof. J. L. Sheldon (University of West Virginia), Dr. J. K. Small (New York Botanical Garden), Prof. E. A. Smith (Geological Survey of Alabama), and Prof. William Trelease (Missouri Botanical Garden). To all the above-named persons thanks are due for helpful cooperation.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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HE SOURCE OF THE DRUG DIOSCOREA, WITH A CONSIDERATION OF THE DIOSCOREÆ FOUND IN THE UNITED STATES.

AXONOMIC HISTORY OF THE DIOSCOREÆ OF THE UNITED STATES.

Dioscorea, an extensively developed genus in the Tropics of both emispheres, is represented in the eastern and central United States y five species. Of this number, two are described for the first time n this paper; the others have had a long and involved bibliographic istory.

In 1705 Plukenet[a] published "Bryoniae nigrae similis floridana, muscosis floribus quernis, foliis subtus lanugine villosis, medio nervo in spinulam abeunte." In 1839 Gronovius[b] referred Plukenet's plant to Dioscorea, in the following account of a specimen which Clayton had sent him from Virginia:

> Dioscorea foliis cordatis acuminatis, nervis lateralibus ad medium folii terminatis. Mas.
>
> Bryoniae nigrae similis Floridana, etc. Plukn., Amalth., p. 46, t. 375, f. 5.
>
> Lupuli species late scandens, foliis cordiformibus venosis, alia flore, alia semine foecunda, flores albos steriles in spica pendula ferens, seminibus membranis extantibus alatis, vasculo quoque seminali membranaceo triquetro inclusis, plurimis in racemos ad modum Lupulorum dense congestis. Clayt. n. 94.

The only Dioscorea ascribed by Linnæus to the present area of the United States was in part based upon the above citations from Plukenet and Gronovius. He treated it as follows:[c]

> 7. Dioscorea [villosa] foliis cordatis alternis oppositisque, caule laevi.
>
> Dioscorea foliis cordatis acuminatis: nervis lateralibus ad medium folii terminatis. Gron. Virg. 121.
>
> Bryoniae nigrae similis floridana, muscosis floribus quernis, foliis subtus lanugine villosis: medio nervo in spinulam abeunte. Pluk. Alm. 46, t. 375, f. 5.
>
> Habitat in Virginia, Florida.

In attempting to decide upon the application of the name *Dioscorea villosa*, it was but natural to inquire whether there was any specimen so called in the herbarium of Linnæus. Dr. B. Daydon Jackson, secretary of the Linnæan Society, very courteously looked into the matter, and wrote as follows:

---

[a] Amaltheum, p. 46, t. 375, f. 5.

[b] Flora Virginica, ed. 1, p. 121.

[c] Species Plantarum, ed. 1 (1753), ii, p. 1033.

> On referring to the Linnæan herbarium, I found only one American specimen. * * * At the bottom of the sheet is the note by Linné himself, "6 K sativa," to which Smith has added in pencil, "non est;" K=Kalm. I do not find any specimen named by Linné "*villosa*" in his herbarium, but as *sativa* is an East Indian species, and the specimen is of Kalm's collection, it is patent that there is a blunder.

Since Kalm is not mentioned in the treatment of *Dioscorea villosa*, and since no localities but Virginia and Florida (these obviously refer to the citations from Gronovius and Plukenet) are mentioned by Linnæus, we can by no means typify *D. villosa* by the Kalm specimen.[a] The species must therefore be interpreted in the light of the diagnosis and synonymy given by Linnæus.

Doctor Rendle, of the British Museum, has kindly sent a photograph and description of the specimen which Clayton collected in Virginia and sent to Gronovius. It is identical with the most widely distributed Dioscorea of our range—not the most characteristic species of Virginia, to be sure, but the one which would probably have been collected in the coastal part of the State. In the matter of pubescence the species varies considerably, but, according to Doctor Rendle, the Gronovian specimen is glabrous except for puberulence on the veins and venules of the lower leaf face. It can not, therefore, have been seen by Linnæus at the time he wrote the Species Plantarum, for he would not have applied the adjective "*villosa*" to an almost glabrous plant. As a matter of fact, the specific name came from Plukenet's "Bryoniae nigrae similis floridana, muscosis floribus quernis, foliis subtus lanugine *villosis*, medio nervo in spinulam abeunte." This characterization and the figure which accompanies it are altogether vague, and in at least one point, the description of the flowers as four parted, not even in accord with the generic concept of Dioscorea. If we typify *Dioscorea villosa* by the Gronovian specimen, as there is some warrant for doing because of the fact that the first-cited locality in the Species Plantarum is Virginia, we must call a widely distributed and abundant plant by a name which is altogether inept. Richard[b] found a way out of this difficulty by renaming the northern plant, which is identical with the Gronovian specimen. His treatment follows:

> D. [paniculata] caule laevi foliis brevibus, cordatis, acuminatis, racemo masc. e plurimis racemulis filiformibus quasi-paniculatim composito; capsula rotundata glabra.

---

[a] A photograph of Kalm's specimen, kindly sent by Doctor Jackson, shows that it should be referred to the species treated in this paper as *Dioscorea paniculata*.

[b] Michaux, Flora Boreali-Americana (1803), ii, p. 239.

D. villosa Linn.
D. quaternata et quinata Gmel.
Obs. Cultura saepe fit glabra.
Hab. a Canada ad Carolinam.

There is no reason why the name *Dioscorea paniculata* should not be adopted, for the description and range implicitly exclude the dubious plant of Plukenet.

The Vienna code provides for the rejection of names which are likely to remain permanent sources of confusion and error. On this ground the name *Dioscorea villosa* should surely be dropped. The Linnæan diagnosis differs in only one word from that of *D. sativa:*

6. Dioscorea [sativa] foliis cordatis alternis, caule laevi.
7. Dioscorea [villosa] foliis cordatis alternis oppositisque, caule laevi.

Moreover, the single character which Linnæus used to distinguish his *Dioscorea villosa* from his *D. sativa* (leaves, in the former species, alternate *and opposite*) did not apply either to Plukenet's plant or to that of Gronovius. The Gronovian specimen at the British Museum has all the leaves alternate. The sheet bears this annotation: "Hinc inde folia fert opposita, unde potius dicenda Dioscorea foliis cordatis alternis oppositisve." Plukenet's plate shows no opposite leaves. As Lamarck[a] pointed out in the passage quoted below, the character "foliis oppositis" had a bibliographic origin with Plumier and Rumphius, whose *Polygonatum scandens altissimum, foliis Tamni* and *Ubium nummularium* are included by Linnæus in *Dioscorea villosa*, although he does not cite them.

> Je crois qu'une Igname dont les feuilles sont les unes alternes & les autres oposées, est un être de raison; que Linné n'a établi son *Dioscorea villosa* que sur les livres, en voulant faire regarder comme la même plante le *Bryoniae nigrae similis Floridana* de Plukenet, le *Polygonatum scandens altissimum* . . . de Plumier, enfin *l'Ubium nummularium* de Rumphe, qui sont trois plantes très-différentes entr'elles. Mais la plante de Plukenet n'a aucunes feuilles oposées, constatées par l'observation; au contraire, celle de Plumier, que j'ai vue, & que je décris ci-dessous, n'a aucunes feuilles alternes. Quelle est donc cette Igname de la Virginie & de la Floride, qui a en même temps des feuilles opposées & des feuilles alternes? Je n'en trouve aucun indice, soit dans les livres, soit dans les Herbiers que j'ai pu visiter. Au reste, la figure citée de Plukenet (t. 375, f. 5), ressemble beaucoup à la plante que l'on cultive au Jardin du Roi sous le nom de *Dioscorea sativa*, plante qui y subsiste en pleine terre, sans que la gelée fasse périr sa racine, ce qui me fait présumer que cette même plante n'est point des Indes, mais qu'elle est réellement originaire de la Virginie.

While Linnæus was writing the Species Plantarum, Burman was engaged in editing works of Rumphius[b] and of Plumier.[c] An appendix[a] to the Herbarium Amboinense contains an "Index universalis," in which *Ubium nummularium* is referred to *Dioscorea villosa*. In his preface Burman states that the Linnæan references were taken from a dissertation published by Stickman under the direction of Linnæus in 1754, and therefore contemporaneous in preparation with the Species Plantarum. The dissertation was reprinted in the Amoenitates Academicae.[b]

---

[a] Encyclopèdie Méthodique Botanique, iii (1789), p. 231.

[b] Rumphii Herbarium Amboinense (1741–1755).

[c] Plantarum Americanarum fasciculus (I, II . . . etc.), continens plantas quas olim Carolus Plumierius detexit, eruitque atque in Insulis Antillis ipse depinxit (1757).

The evidence that Plumier's *Polygonatum scandens altissimum, foliis Tamni* is included in the Linnæan concept of *Dioscorea villosa* is not so convincing as in the case of *Ubium nummularium*. The two plants are made synonyms in Burman's edition of Plumier, but whether or not with the knowledge of Linnæus it is impossible to say. Plumier's plate is of an opposite-leaved Dioscorea from the West Indies, a member of a section of the genus to which our species have no resemblance.

As compared with *Dioscorea villosa*, none of our other species are difficult of interpretation. Walter[c] published Anonymos (Dioscoreae affinis?) quaternatus, foliis cordatis septemnerviis, nervorum pari extimo bifido, acuminatis, infimis quaternis deinde ternis binis alternisque, caule sinistrorsum volubili, racemis axillaribus pendulis, floribus sursum assurgentibus, and Anonymos (Dioscoreae affinis?) quinatus, foliis peltato-cordatis, 9-nerviis, foliis infimis quinis. Gmelin[d] later copied the diagnoses and published the binomials *Dioscorea quaternata* and *D. quinata*. Walter's herbarium, at the British Museum, contains specimens of neither plant. *Dioscorea quaternata* was accepted as a good species by Pursh,[e] Nuttall,[f] Elliott,[g] Beck,[h] and Kunth,[i] and is interpreted in the traditional way in this paper. *D. quinata*, on the other hand, has always been an enigma.

In 1813 Muhlenberg[j] published *Dioscorea glauca*, a nomen subnudum. Fortunately, however, his plant is as readily identified from the descriptive name which he chose, and from the locality, as though he had written a full description. He recognized two species, which he treated as follows:

---

[a] Rumphii Herbarii Amboinensis Auctuarium (1755).

[b] Amoenitates Academicae, iv. Diss. lvi, Herbarium Amboinense sub praesidio D. D. Car. Linnaei proposuit Olavus Stickman. Upsaliae, 1754, Maj. 9.

[c] Flora Caroliniana (1788), p. 246.

[d] Linnaei Systema Vegetabilium, ed. 13 (1791), i, p. 581.

[e] Flora Americae Septentrionalis (1814), i, p. 251.

[f] Genera of North American Plants (1818), ii, p. 238.

[g] Botany of South Carolina and Georgia (1824), ii, p. 704.

[h] Botany of the Northern and Middle States (1833), p. 355.

[i] Enumeratio Plantarum (1850), v, p. 336.

[j] Catalogus Plantarum Americae Septentrionalis (1813), p. 92.

Dioscorea: (1) villosa ♃ hairy Pens. fl. Jun. Virg; (2) glauca ♃ glaucous Pens. fl. Jun.

Only two species have been found in a large series of specimens from Pennsylvania. One of them, *Dioscorea paniculata*, corresponds to the *D. villosa* of Muhlenberg, and the other must therefore be called *D. glauca*. There is nothing to represent Muhlenberg's name in his herbarium at the Philadelphia Academy of Natural Sciences, but there can not be the least doubt that it has been applied to the correct plant.

Rafinesque[a] described four Dioscoreæ in 1836. Two of them *D. megaptera* and *D. hexaphylla* may be referred to *D. glauca*, and one, *D. repanda*, may be divided between *D. glauca* and *D. quaternata*. The other, *D. longifolia*, described from leaves only, it is impossible to identify.

In 1850 Kunth[b] published *Dioscorea pruinosa*. No specimen is preserved at Berlin. From his full description, however, it seems clear that the plant should be referred to *D. glauca*.

Between the years 1850 and 1909 all of our Dioscoreæ were treated in botanical works as one species under the name *Dioscorea villosa*. In the seventh edition of Gray's Manual (1909) the editors departed from current usage in taking up *D. villosa* var. *glabra*, a name obscurely published by Mr. C. G. Lloyd in 1880,[c] and afterwards used in various medical works.[d] Careful study of all the evidence available has shown that this name is likewise a synonym of *Dioscorea glauca*. Mr. Lloyd's very valuable observations on the medicinal rhizomes of the two plants distinguished by him as *D. villosa* and *D. villosa* var. *glabra* will be given due attention in another connection.

SYNOPSIS OF THE SPECIES OF DIOSCOREA.

Staminate inflorescences solitary and occurring only in the leaf axils.
  Lower leaves verticillate in 4's to 7's.
    Leaf blades green below when mature, usually glabrous, 1. *D. quaternata*.
    Leaf blades glaucous below when mature, generally hirtellous, 2. *D. glauca*.

---

[a] New Flora of North America, second part, Neophyton (1836), pp. 88–89.

[b] Enumeratio Plantarum, v. (1850). p. 339.

[c] King, John, and Lloyd, John Uri, Supplement to the American Dispensatory (1880), pp. 81–83.

[d] Several editions of King's American Dispensatory, revised by H. W. Felter and J. U. Lloyd.

A Treatise on Dioscorea and Sulphurous Acid. Drug Treatise No. 14, issued by Lloyd Brothers (1905).

Lower leaves all alternate, or the three lowest subapproximate or verticillate.
  Internodes strictly glabrous. Fruiting racemes many fruited.
    Leaves pubescent beneath------------------------3. *D. paniculata.*
    Leaves altogether glabrous--------------3. *D. paniculata glabrifolia.*
  Internodes hairy. Fruiting racemes 1 to 4 fruited------4. *D. hirticaulis.*
Staminate inflorescences solitary or fasciculate in the leaf axils, and terminating the stem--5. *D. floridana.*

1. *Dioscorea quaternata* (Walt.) Gmel. Rhizomes about 1 cm. in diameter, straight or sometimes forked, with few or no short lateral branches. Stems 1 to 2 m. long, rigid and erect below the first node, requiring support above. Lower leaves verticillate by 5's or 6's (rarely 4's or 7's); upper leaves alternate. Petioles of the lower leaves densely pubescent at base and apex, sometimes glabrate in age. Leaf blades cordate, repand, green on both sides, usually strictly glabrous except for the dense pubescence at the insertion of the petiole. Staminate inflorescences paniculate, solitary in the leaf axils, occuring even in the axils of the lower verticillate leaves. Pistillate inflorescences few flowered. Fruit 2 to 3 cm. long, very variable in shape.

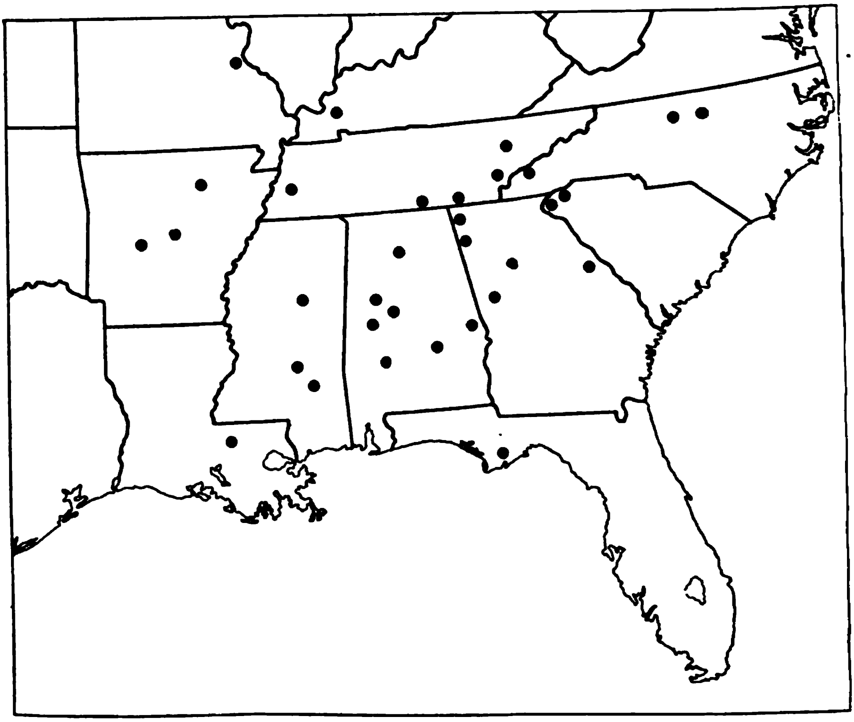

FIG. 1.—Map of the southeastern portion of the United States, showing the distribution of *Dioscorea quaternata.*

The distribution of this species, as shown in figure 1, is based upon the following material:

North Carolina.—Guilford County, *Biltmore Herb.*, 364 a; Orange County, W. *Ashe;* Swain County, *H. C. Beardslee* and *C. A. Kofoid*, July 25, 1891.

South Carolina.—Oconee County, *H. D. House*, 3470 and 2120; Pickens ounty, *H. D. House*, 3079.

Georgia.—De Kalb County, *H. Eggert*, May 22, 1897, and *W. W. Ashe*, May, 96; Floyd County, *Chapman Herb.;* McDuffie County, *H. H. Bartlett*, 1722 nd 1733; Walker County, *Percy Wilson*, 197; Meriwether County, *S. M. Tracy*, 08.

Alabama.—Bibb County, *E. A. Smith*, July 20, 1879; Cullman County, *H. ggert*, June 21, 1897, and *C. F. Baker*, May 18, 1897; Hale County, *S. Watson*, 1857; Lee County, *F. S. Earle* and *C. F Baker*, April 24, May 8, and October , 1897; Montgomery County, *C. Mohr;* Tuscaloosa County, *E. A. Smith*, 1287 nd 1516; Wilcox County, *S. B. Buckley*, May, 1839.

Florida.—Franklin County, *Chapman.*

Louisiana.—East Baton Rouge Parish, *W. R. Dodson.*

Mississippi.—Choctaw County(?), *I. M. Clute*, 68; Jones County, *S. M. Tracy*, 355; Smith County, *S. M Tracy*, August 22, 1903.

Arkansas.—Garland County, *William Trelease*, October 3, 1898, and *S. E. eek*, August 19, 1889; Independence County, *F. V. Coville*, 180; Pulaski ounty, *H. E. Hasse*, April 11, 1886.

Missouri.—Jefferson County, *H. Eggert*, July 15, 1892.

Tennessee.—Franklin County, *A. Gattinger;* Hamilton County, *F. Lamson-cribner*, May 21, 1890; Haywood County, *S. M. Bain*, June 13, 1893; Knox ounty, *A. Ruth*, 779 and 1200 a; Monroe County, *F. Lamson-Scribner*, June 29, 890.

Kentucky.—Lyon County, *W. W. Eggleston*, 4674.

2. *Dioscorea glauca* Muhl. Rhizomes 1 cm. or more in diameter, ften forked and with many short lateral branches equal in diameter to the rhizome, usually much contorted and forming dense masses. Stems 1 to 3 m. long, rigid and erect below the first node, requiring support above. Lower leaves verticillate in whorls of 5 to 7; upper leaves alternate. Petioles densely pubescent at the apex. Leaves larger than in *D. quaternata*, less markedly repand or not at all so, usually sparsely hirtellous beneath, but often glabrous, always glaucous when mature. Paniculately branched staminate inflorescences solitary, occurring in all the leaf axils. Pistillate inflorescences few flowered; fruits 2 to 3 cm. long.

Dioscorea glauca is essentially a plant of the mountains, although in the northern part of its range it is found near sea level. In the lowlands southward it is replaced by the closely related *D. quaternata*. As will be seen from the map (fig. 2) the ranges of the two species hardly overlap.

The following specimens have been examined:

Pennsylvania.—Allegheny County, *J. A. Shafer*, 590, and *C. C. Mellor*, June 7, 1889; Fulton County, *Witmer Stone*, June 4, 1905; Huntingdon County, *O. E. Jennings*, May 17, 1904; Lancaster County, *J. J. Carter*, May, 1870, and *A. A. Heller*, June 5, 1900; Susquehanna County, *A. Stengel*, May 29, 1886; Westmoreland County, *O. E. Jennings*, May 19, 1904; York County, *J. N. Rose* and *J. H. Painter*, 8123.

Delaware.—Newcastle County, *William M. Canby*, July, 1893.

Maryland.—Garrett County, *G. A. Eifrick*, May, 1902; Montgomery County, *A. Chase*, 2313 and 2827½, and *H. H. Bartlett*, 1821; Prince Georges County, *A. Chase*, 2215; District of Columbia, *E. S. Steele*, 67, and *H. D. House*, 709.

Virginia.—Alexandria County, *A. S. Hitchcock*, September, 1904, and *L. H. Dewey*, 239; Bedford County, *A. H. Curtiss*, 43953; Campbell County, *S. B. Buckley;* Fairfax County, *E. L. Morris*, June, 1896, and *L. H. Dewey*, 232; Loudoun County, *A. Chase*, 2244; Russell County, *C. L. Alsberg*, 54 and 120; Smyth County, *J. K. Small*, June 4, 1892.

West Virginia.—Barbour County, *J. M. Greenman*, 93; Monongalia County, *O. E. Jennings*, July 4, 1909; Preston County, *J. L. Sheldon*, 1454, and *E. S. Steele*, August 18, 1898; Upshur County, *W. M. Pollock*, May 30, 1895, and May 31 and June 12, 1897.

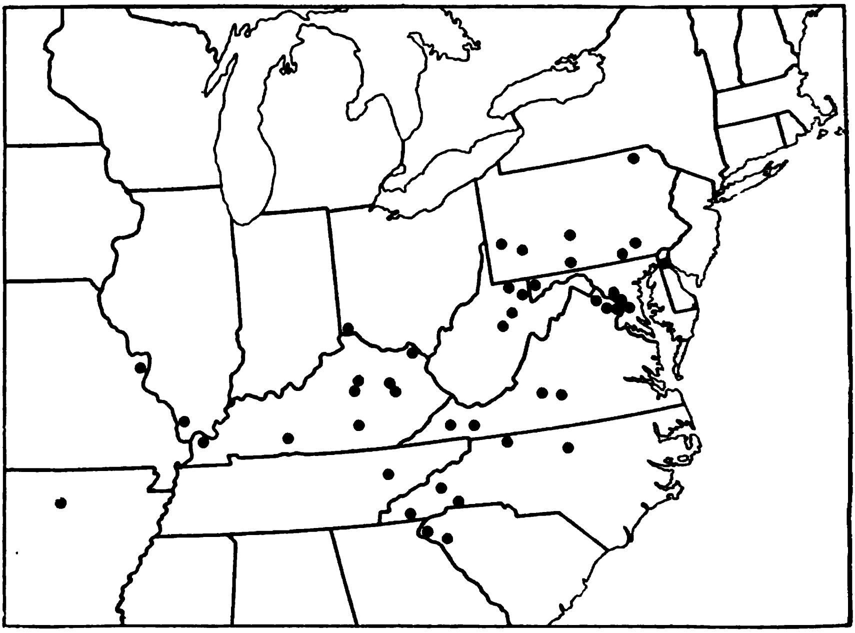

FIG. 2.—Map of the eastern portion of the United States, showing the distribution of *Dioscorea glauca*.

Ohio.—Hamilton County, *C. G. Lloyd*.

Illinois—Union County, *F. S. Earle*, 763, and *Mrs. C. Butler*, August 13, 1880.

Kentucky.—Fayette County, *W. A. Kellerman*, in 1882; Greenup County, *John Butler*, in 1909; Jessamine County, *H. Garman;* McCracken County, *Biltmore Herb.*, 364 c; Menifee County, *H. Garman*, May 8, 1893; Pulaski County, *C. W. Mathews*, July 11, 1892; Warren County, *S. F. Price*, May 21, 1900; Wolfe County, *M. L. Didlake*, June, 1898.

Missouri.—St. Louis County, *N. M. Glatfelter* (?), 517.

Tennessee.—Knox County, *F. Lamson-Scribner*, May 14, 1889.

North Carolina.—Buncombe County, *Biltmore Herb.*, 364, and *F. Crayton* and *W. W. Eggleston*, 4398; Macon County, *L. R. Gibbs*, in 1881; Orange County, *W. W. Ashe*, June, 1898; Polk County, *J. R. Churchill*, May 30, 1899, and *E. C. Townsend*, April 29, 1897; Surry County, *H. H. Rusby*, June 18, 1909.

South Carolina.—Anderson County, *L. R. Gibbs*, in 1885; Oconee County, *A. P. Anderson*, 1502.

3. *Dioscorea paniculata* Michx. Rhizomes long and slender, simple
rarely forked, less than 1 cm. in diameter, with a few short lateral
anches of less diameter. Stem 1 to 4 m. long, flexucus, glabrous.
eaves all alternate, or two or three of the lowest subapproximate,
ubescent or puberulous beneath. Petioles glabrous at the insertion
f the blade, or, if pubescent, less densely so than the blades. Stami-
ate inflorescences solitary, borne only in the leaf axils of the upper
alf of the stem, the three or four lowest less branched than those
igher up. Pistillate inflorescences densely many fruited. Capsules
cm. long or less.

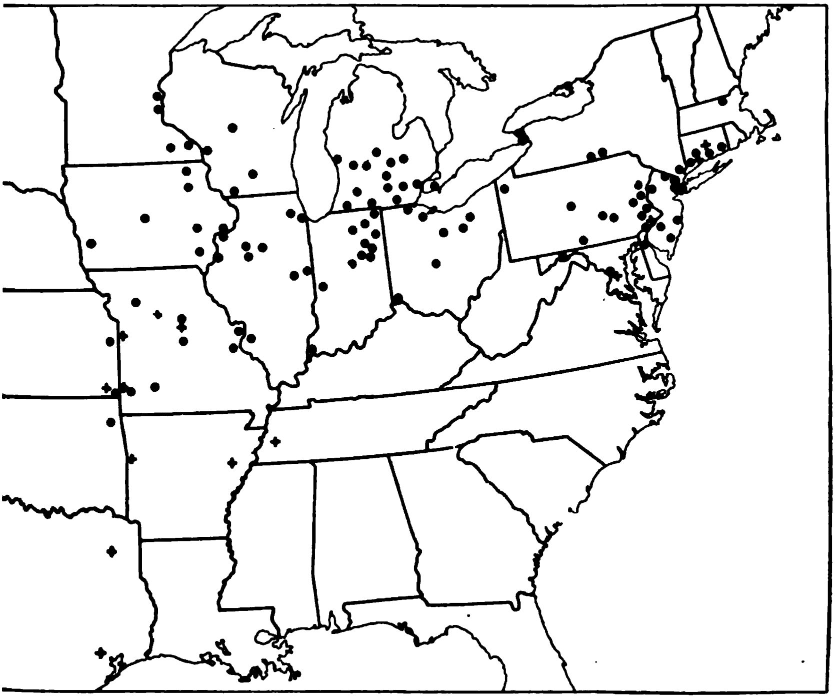

FIG. 3.—Map of the eastern portion of the United States, showing the distribution of *Dioscorea paniculata* (by dots) and its variety *glabrifolia* (by crosses).

Var. *glabrifolia* Bartlett.[a] Leaves altogether glabrous. This variety replaces the typical form of the species in the southwestern part of the range. Various northeastern specimens are indistinguishable from the southwestern plant, but may be genetically distinct from it. In the distribution map (fig. 3) the range of the variety is shown by crosses.

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[a] *Dioscorea paniculata glabrifolia* var. nov. Foliis glabris exceptis, formae speciei typicae omnino similis. *A. S. Hitchcock*, 830 (pro parte) "Woods, Cherokee Co., Kansas, 1896."

The following specimens of *Dioscorea paniculata* have been examined:[a]

Connecticut.—Fairfield County, *C. L. Pollard*, 115; Middlesex County, *J. H. Redfield*, 7952, and *S. B. Buckley*, September, 1835; New Haven County, *C. H. Bissell*, 203, and *A. L. Winton*, July 8, 1886; New London County, *G. R. Lumsden*, July 16, 1885.[b]

New York.—Chemung County, *T. F. Lucy*, 712; New York County, *N. L. Britton*, July 22, 1879; Tioga County, *F. V. Coville*, June 4, 1887, and *F. E. Fenno*, 401; Westchester County, *G. V. Nash*, July 2, 1896.

New Jersey.—Atlantic County, *C. A. Gross;* Bergen County, *N. L. Britton*, September, 1883; Camden County, *E. B. Bartram*, August 3, 1907; Hudson County, *A. C. Hexamer* and *F. W. Maier*, August 17, 1852, and *William M. Van Sickle*, July 1, 1894; Ocean County, *J. H. Grove*, July 16 and August 21, 1908; Passaic County, *G. V. Nash*, July, 1889; Warren County, *Albrecht Jahn*, September 14, 1895, *Thomas C. Porter* and *A. A. Tyler*, June 27, 1896.

Delaware.—Newcastle County, *A. Commons*, July, 1866.

Maryland.—Allegany County, *Howard Shriver*, in 1894; District of Columbia, *F. Blanchard*, September 17, 1890, *L. F. Ward*, July 8, 1878, and *C. L. Pollard*, 605.

Pennsylvania.—Bucks County, *Bayard Long*, July 6, 1909; Center County, *W. A. Buckhout*, October, 1909; Crawford County, *O. E. Jennings*, August 19, 1904, and *J. A. Shafer*, July 23, 1901; Dauphin County, *J. K. Small*, July 18, 1888; Delaware County, *S. S. Van Pelt*, June 24, 1906; Franklin County, *I. A. Keller*, July 28, 1895; Lebanon County, *J. K. Small*, December, 1891; Lehigh County, *A. F. K. Krout*, June, 1878; Monroe County, *Joseph Crawford*, July 4, 1896; Montgomery County, *Alexander MacElwee*, June 26, 1892; Northampton County, *A. A. Tyler*, 550, and *Bayard Long*, June 29, 1908; Philadelphia County, *J. H. Redfield*, 7951.

Ontario.—Essex County, *Macoun*, July 24, 1892; Lincoln County, *W. C. McCalla*, 244; Welland County, *Cameron*, August, 1892.

Ohio.—Franklin County, *E. B. Williamson*, June 22, 1897; Hamilton County, *C. G. Lloyd*, June 25, 1890, and *W. H. Aiken*, June 15, 1902; Lucas County, *Lewis Schultz*, 1705; Richland County, *E. Wilkinson*, 10214; Sandusky County, *M. J. Persing*, July 10, 1897; Summit County, *L. D. Stair*, June 26, 1896; Wayne County, *A. Russ*, 435, and *A. D. Selby* and *J. W. T. Duvel*, 436.

Michigan.—Branch County, *J. Shaddick*, July 29, 1896; Cass County, *H. S. Pepoon*, 452; Genesee County, *D. Clark;* Gratiot County, *C. A. Davis*, July 10 and October, 1892; Ingham County, *C. F. Wheeler*, June 20, 1895; Ionia County, *F. P. Daniels*, June, 1896; Jackson County, *Houghton*, July 13, 1838; Kalamazoo County, *Houghton*, August 2, 1838; Kent County, *A. A. Crozier*, July 11, 1886; Lenawee County, *W. J. Beal*, in 1886; Muskegon County, *C. D. McLouth*, September 7, 1898; Shiawassee County, *G. H. Hicks*, July 13, 1889; Washtenaw County, *Houghton*, July 2, 1838; Wayne County, *William Boott*, June 26, 1871.

Wisconsin.—Dane County, *H. L. Russell*, June 20, 1887, and *L. S. Cheney*, July 5, 1890; La Crosse County, *L. H. Pammel*, July, 1887; Lafayette County, *L. S. Cheney*, June 26, 1890; Wood County, *B. M. Vaughan*, July, 1883.

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[a] The occurrence of *Dioscorea paniculata* in Middlesex County, Massachusetts, shown in figure 3, is based upon Bigelow's report of the plant as "rare" in "woods on the Concord turnpike." (Florula Bostoniensis, 2d ed., 1824, p. 369.) It has not been reported since.

[b] Of all the specimens cited in this synopsis, only this one had branched pistillate inflorescences.

innesota.—Chisago County, *B. C. Taylor*, August, 1892; Olmsted County, *s. George Ainslie*, May 28, 1895; Washington County, *H. Eggert*, July 12, 2; Winona County, *J. M. Holzinger*, August 21, 1888.

ndiana.—Allen County, *C. C. Deam*, 1157; Blackford County, *C. C. Deam*, 1; Grant County, *C. C. Deam*, 2177; Huntington County, *C. C. Deam*, 2146; sciusko County, *C. C. Deam*, 3205; Noble County, *C. C. Deam*, 316; Parke nty, *H. H. Bartlett*, June 25, 1903; Posey County, *C. C. Deam*, 910; Steuben nty, *C. C. Deam*, June 16, 1903; Tippecanoe County, *H. B. Dorner*, July 4, 1; Wells County, *C. C. Deam*, 4.

llinois.—Champaign County, *M. B. Waite*, June 28, 1886; Cook County, *A. ase*, June 1, 1896; Dupage County, *L. M. Umbach*, August 18, 1897, June 16 July 2, 1898; Henderson County, *H. N. Patterson*, 43954; Marshall County, *H. Chase*, 1488; Peoria County, *F. E. McDonald*, July, 1893; St. Clair County, *Eggert*, June 24, 1875, and August 28, 1878; Stark County, *V. H. Chase*, 623; ck Island County, *C. C. Parry*, July, 1865; Vermilion County, *M. B. Waite*, ne 24, 1886.

owa.—Fayette County, *B. Fink*, 472; Henry County, *J. H. Mills*, 531; Johnson unty, *Fitzpatrick*, June, 1896; Pottawattamie County, *F. V. Hayden*, July 5, 3; Scott County, *C. C. Parry;* Story County, *A. S. Hitchcock;* Winneshiek unty, *E. W. D. Holway*, June 30, 1882.

Missouri.—Boone County, *F. P. Daniels*, June 13, 1903; Caldwell County, *E. Townsend*, September, 1869; Cole County, *O. Krause*, June, 1867; Greene unty, *J. W. Blankinship*, 2477; Jasper County, *E. J. Palmer*, 527; Jefferson unty, *H. Eggert*, June 26, 1892; St. Louis County, *H. Eggert*, June 14, 1893.

Kansas.—Cherokee County, *A. S. Hitchcock*, 830 (*pro parte*); Miami County, *H. Oyster.*

Oklahoma.—District 2, Indian Territory, *B. F. Bush*, 1137.

The following specimens of the variety *glabrifolia* have been amined:

Connecticut.—Middlesex County, *S. B. Buckley*, September, 1835; New Haven unty, *Robbins.*

Pennsylvania.—Philadelphia County, *S. S. Van Pelt*, July 10, 1908.

Maryland.—Prince Georges County, *H. H. Bartlett*, 1873.

Tennessee.—Haywood County, *S. M. Bain*, 321.

Missouri.—Boone County, *F. P. Daniels*, June, 1903; Cass County, *G. C. roadhead*, June, 1865; Jasper County, *B. F. Lutman*, August 1, 1901, and *E. J. lmer*, 832; Saline County, *William Trelease*, June 23, 1886.

Kansas.—Cherokee County, *A. S. Hitchcock*, 830 (*pro parte*).

Arkansas.—St. Francis County, *William Trelease*, August 20, 1897; Sebastian ounty, *J. M. Bigelow*, in 1853–54.

Texas.—Harris County, *J. F. Joor*, June 20, 1877; Upshur County, *J. Reverhon*, 2497 and 4033.

4. *Dioscorea hirticaulis* Bartlett.[a] Rhizome less than 1 cm. in iameter, simple or rarely forked, nearly straight, bearing short lat-

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[a] ***Dioscorea hirticaulis*** sp. nov. Rhizoma horizontale, plerumque simplex vel aro furcatum, usque ad 50 cm. longum, crassitudine ca. 8 mm.; ramulis paucis ateralibus abortivis quam rhizomate multo tenuioribus, 0.5–2 cm. longis; aulium cicatricibus saepe inter se 10–12 cm. distantibus saepe binis trinisve pproximatis. Caulis gracilis scandens flexuosus 2–3–metralis, hirtellus. Folia nfima 3 verticillata vel propinqua, superne alterna, laminis cordatis 7–9 nervils, upra glabris subtus griseo-pubescentibus, margine saepissime repandis; petiolis,

eral branches of 2 to 3 mm. diameter. Stem 1 to 3 m. long, flexuous, weak, pubescent. Leaves all alternate, or the three lowest verticillate or subapproximate, griseous-pubescent beneath and also, though not so densely, on the apex of the petiole. Staminate inflorescences solitary in the leaf axils of the upper half of the stem, the lowest simple or with one branch, the others increasingly paniculate. Pistillate inflorescences developing from 1 to 4 fruits, which are about 2 cm. long.

Dioscorea hirticaulis is probably confined to the region of the fall line and to the Coastal Plain, for no stations are known further inland. As it occurs about Thomson, Ga., it is confined to the branch swamps, where its long rhizomes run horizontally barely beneath the surface of the black muck soil. The only other Dioscorea of the region, *D. quaternata*, with which it shows not the least intergradation, has a totally different habitat.

Specimens examined:

North Carolina.—Cumberland County, *Biltmore Herb.*, 364 b.
South Carolina.—Berkeley County, *H. W. Ravenel.*
Georgia.—McDuffie County, *H. H. Bartlett*, 1468.

5. *Dioscorea floridana* Bartlett.[a] Rhizomes unknown. Stem flexuous, twining. Leaves alternate, entirely glabrous, green above, paler beneath. Staminate inflorescences paniculate, terminating the stem and also fasciculate by twos and threes in the upper leaf axils, the larger axillary inflorescences sometimes 40 cm. long. Pistillate inflorescences solitary, 5 to 7 flowered. Fruits about 2 cm. long, similar in shape to those of *D. paniculata.*

This species is very clearly distinguished from our other species by the position of the staminate inflorescences. In material collected by Mr. Harper in Georgia the larger inflorescence of an axillary fascicle exceptionally bears one or two leaf-like bracts. As at the end

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praecipue ad apicem versus, hirtellis. Inflorescentiae masculae solum in foliorum axillis superiorum positae, densiflorae, inferiores vix ramosae, superiores paniculatae; pedunculo perbrevi ramulisque sub lente pubescentibus, alato-angulatis. Perigonium 6-partitum immaculatum. Stamina 6, filamentis perbrevibus; antheris bifido-didymis. Spicae femineae solitariae 1–4 florae: capsulis circumscriptione obcordatis 2 cm. longis, aetate castaneis. Semina fusca.—*H. W. Ravenel*, "Santee Canal, South Carolina" (♂); *H. H. Bartlett*, 1468, "Branch swamp," McDuffie County, Georgia, September 18, 1908 (♀).

[a] *Dioscorea floridana* sp. nov. Rhizoma ignotum. Caulis scandens, flexuosus, glaber. Folia cordata, alterna, utrinque glabra, supra viridia, subtus pallidiora, 7-nervia, nervis exterioribus bifurcatis. Inflorescentiae masculae paniculiformes et caulem terminantes et binis trinisve in foliorum axillis superiorum fasciculatae; floribus aut singulis aut binis sessilibus, valde flavis, maculatis; staminibus haud didymis. Spicae femineae pendulae, solitariae, ca. 6-florae. Capsulae forma eis *D. paniculatae* similes, ca. 2 cm. longae.—"Moist thickets, Lake City, Fla.," P. H. Rolfs, 266 (♂), June 18, 1894; Charleston, S. C., in Herb. Bost. Soc. Nat. Hist. (♀).

f the stem, however, the transition from leaves to subulate bracts is ot gradual but sharp.

Specimens examined:

South Carolina.—Charleston County (specimen in Herb. Bost. Soc. Nat. Hist.).

Georgia.—Jefferson County, *M. H. Hopkins*, 91; Sumter County, *R. M. Harper*, 89.

Florida.—Columbia County, *P. H. Rolfs*, 266; Escambia County, *A. H. Curtiss*, 1885.

THE DRUG DIOSCOREA.

According to Mr. C. G. Lloyd the rhizome of Dioscorea was first rought to the attention of "botanic physicians" by Dr. J. L. Riddell[a] in 1835, although before that time it had been used more or less s a "secret remedy."[b] Riddell's account of the plant, which was opied in part by most subsequent writers, was as follows:

> 1501. Dioscorea villosa, Linn. Yam root. China root. May–June. Yellow-rhite. Climbing vine, 6 to 12 f. Root woody, tortuous, echinate. Open woods. ottom lands. Western States. An infusion of the powdered root is to be boiled n a pint of water, and half of it given at once. * * * I have been informed hat Doctor Miller, of Neville, Ohio, values the tincture highly as an expectorant. e says it is also diaphoretic, and, in large doses, emetic."

In 1836, a year later, William Hance[c] published a much fuller ccount of Dioscorea, which, on account of the evidence it affords egarding the identity of the species used at that time, is here quoted n full:

> DIOSCOREA VILLOSA. *Common names—Yam root, China root.*—This plant is a wining and climbing vine, resembling in some respects the morning glory. The oot is of a most singular tortuous form, of a woody consistence, with numerous piny protuberances. It is perennial, and doubtless endures a greater number of ears than the roots of most plants of similar habits. The sprangles are usually near half an inch in thickness, and the whole root in favorable situations is ften found to weigh half a pound. The stem is a climbing annual vine, winding around small shrubs, and insinuating itself among brambles, often attaining the height of 6 or 8 feet. Near the ground the leaves usually appear in verticillate clusters, or whorls, varying in number from two to eight or more in a bunch, dependent on the luxuriance of the soil. Higher up the leaves are alternate. They are always on pretty long footstalks and of the form of a heart, with the point acute and turned to one side; commonly roundish as well as cordate and nearly 2 inches across. Almost always you may count just nine nerves or portions of framework, proceeding from the base toward the apex. The flowers show themselves in May and June; they are very small and white, arranged on little stems which come out just above the leaves. The seeds are triangular, some like buckwheat, though four times as large, with wings at the angles. The yam root grows plentifully in the Western States, delighting in fertile hillsides, thickets, and open woods.

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[a] A Synopsis of the Flora of the Western States (1835).

[b] See Transactions, N. Y. State Eclectic Medical Society, for 1870. D. E. Smith, "Dioscorea."

[c] Howard's Botanic Medicine, ed. 3 (1836), ii, p. 240.

> An infusion of the root is a valuable remedy in bilious colic. An ounce of the powdered root must be boiled in a pint of water, and half of it given at a dose. * * * I have been informed that Doctor Miller, of Neville, Ohio, values the tincture highly as an expectorant. He says it is also diaphoretic, and in large doses emetic.
>
> For the introduction of the dioscorea into this work we are indebted to the kindness of our friend, Dr. J. L. Riddell. He has not informed us upon what principle it is supposed to afford relief in bilious colic, whether as an anodyne, cathartic, or some other. We have no doubt, however, of its value in this complaint, and, at the same time, think it highly probable that further investigation will disclose its usefulness in other diseases.

It will be observed that the plant described by both Riddell and Hance was *Dioscorea glauca* Muhl. The description of the rhizome as "singularly tortuous, with numerous spiny protuberances" and "sprangles usually near half an inch in thickness," and of the leaves as "verticillate, from two to eight in a bunch," leaves no doubt concerning the plant which they used. In this connection it should be observed (see fig. 2) that *D. glauca* occurs in southern Ohio, where Riddell might have observed it. By the time King[a] published his Dispensatory, however, one of the species with slender rhizomes had come into use in eclectic medical practice. King's description included characters of two or three species and was obviously compiled from earlier authors. The rhizome, however, he undoubtedly described from his own knowledge of it as "long, woody, contorted, from an eighth to a fourth of an inch in diameter." He doubtless used *D. paniculata*. This species was also used by W. S. Merrell in the preparation of his "dioscorein," and at that time (about 1850) was the only plant recognized by the eclectic school as "*Dioscorea villosa*." It must be remembered, however, that the "*D. villosa*" of "Howard's Botanic Medicine" was *D. glauca*. The history of dioscorea between 1850 and 1880 can not be better outlined than by quoting from Mr. C. G. Lloyd's article in the Supplement to the eighth edition of King's Dispensatory.[b] In order to make the quotations intelligible the "Plate VII," which is referred to, is here reproduced as figure 4:

> The rhizoma of *Dioscorea villosa* is a favorite therapeutical agent among our eclectic physicians, who have advantageously used it for more than forty years. It is known as wild yam and colic root. The first specimens employed were from the *Dioscorea villosa*, with pubescent leaves (fig. 2, Pl. VII), now known as the "true wild yam." About the year 1850 botanic druggists noticed the admixture by root diggers of the rhizomata represented by figure 1, Plate VII, and for a considerable time rejected it as an adulteration. The diggers insisted, however, that both "roots" were obtained from vines almost identical in appearance (although they can distinguish between them), and finally purchasers were compelled to accept them, more especially as the

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[a] American Eclectic Dispensatory (1854), p. 440.

[b] Supplement to the American Dispensatory, by John King and John Uri Lloyd (1880), pp. 81–83.

ue rhizomata became very scarce. Mr. H. M. Merrell, of Cincinnati, Ohio, whom we are indebted for this information, states that the first heavy ship- ents of the false "wild yam root" to eastern houses were made about 1860, hich article purchasers refused to accept, but after some correspondence, upled with the fact that the true wild yam could not at that time be obtained, e parties concluded to receive it. Since then the two rhizomata have been ld indiscriminately, although but little of the original drug is to be found in e market. Eclectic physicians are aware of the difference between these izomata and refuse to use the "false" variety, insisting that it does not ssess the medicinal properties, and can not safely be substituted for the true." In this connec- on we invite attention the accurate engrav- gs of each variety of e rhizomata in Plate II. [See fig. 4.]

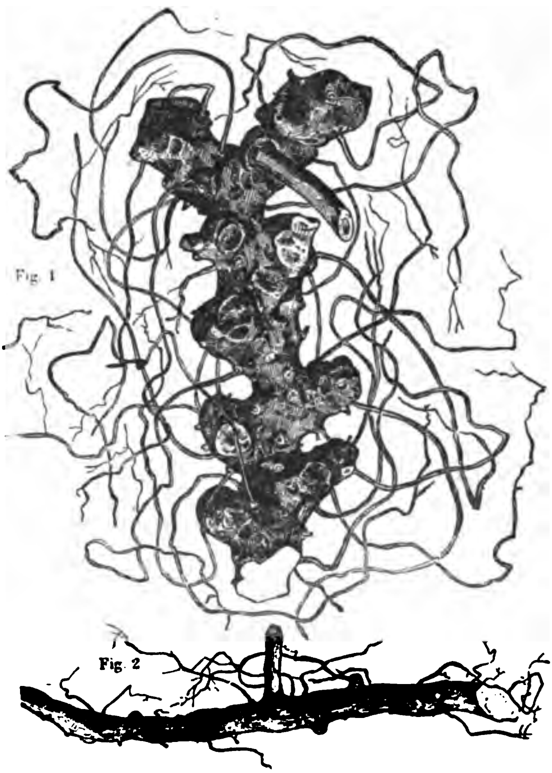

Fig. 4.—Reproduction of Plate 7, "*Dioscorea villosa*," from King and Lloyd's "Supplement to the American Dispensatory." (Reduced one-third.)

The rhizoma of *Dios- rea villosa* (Pl. VII, g. 2) appears in market slender contorted ieces from one-fourth of n inch to half an inch diameter, and often 2 et in length. It is oval, eing flattened above and elow as it creeps in a orizontal position be- eath the surface of the round. It seldom throws ut branches, but occa- ionally little protuber- nces project from its des, being from one- ighth of an inch to an nch in length and about ne-third as large in iameter as the primary hizoma. They are round- ng at the extremity, nd seem to indicate an bortive attempt of the hizoma to throw out branches, but they do not send up the vine. Along the upper side of the rhizoma are stem scars, which are about three-fourths of an inch apart. The epidermis is brown, thin, and scales off, more or less, upon drying, especially when the rhizoma is gathered in the spring, but which is not the case with a good quality of it when dug in autumn. The internal color of the dry rhizoma is whitish, or slightly straw colored, when gathered in the autumn, but it is often brown when collected early in the season; there is no bark to it. Under a magnifying glass the texture of a broken rhizoma appears mealy and perforated with numerous woody bundles. Attached to the lower part of the rhizoma an abundance of strong, wirelike fibers will be observed. * * * *Dioscorea villosa* has one of the firmest of rhizopubescent beneath, and figures 6 and 7, illustrating rhizomes of *D. paniculata* and its variety *glabrifolia*.

When *Dioscorea glauca* grows at low altitudes its rhizome is less branched and contorted than when it grows in the mountains. In the vicinity of Washington, D. C., its rhizome is often as unbranched as the rhizome of *D. quaternata*, and might be mistaken for that species, but its greater diameter still suffices to distinguish it from *D. paniculata*. The form of rhizome which occurs most frequently in the drug trade at the present time is well illustrated by figure 8. This particular specimen was obtained through the kindness of Mr. R. W. Proctor, of Cincinnati, Ohio. As a general rule, collectors of Dioscorea who supply the drug market do not distinguish between

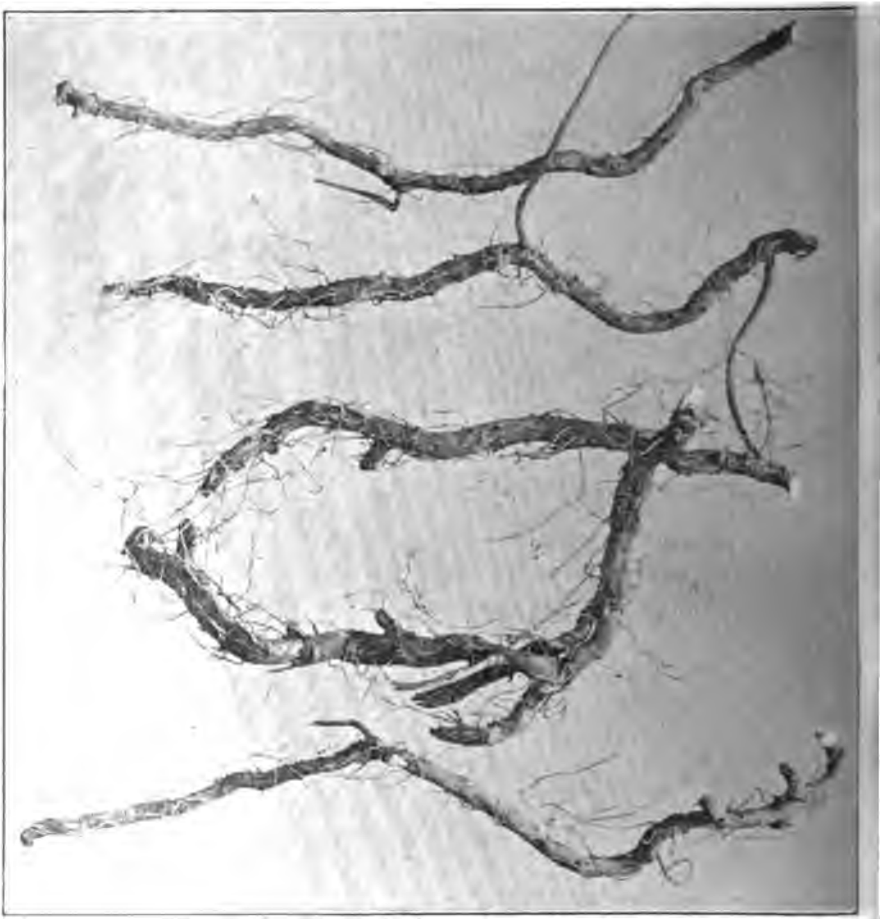

FIG. 7.—Rhizomes of *Dioscorea paniculata* var. *glabrifolia* from Glenndale, Prince Georges Co., Md., collected by H. H. Bartlett. (Two-thirds natural size.)

e different kinds. The same common names are used for all of the ecies. Wild yam is the name used over the largest area. The llowing names have also been reported by correspondents of the

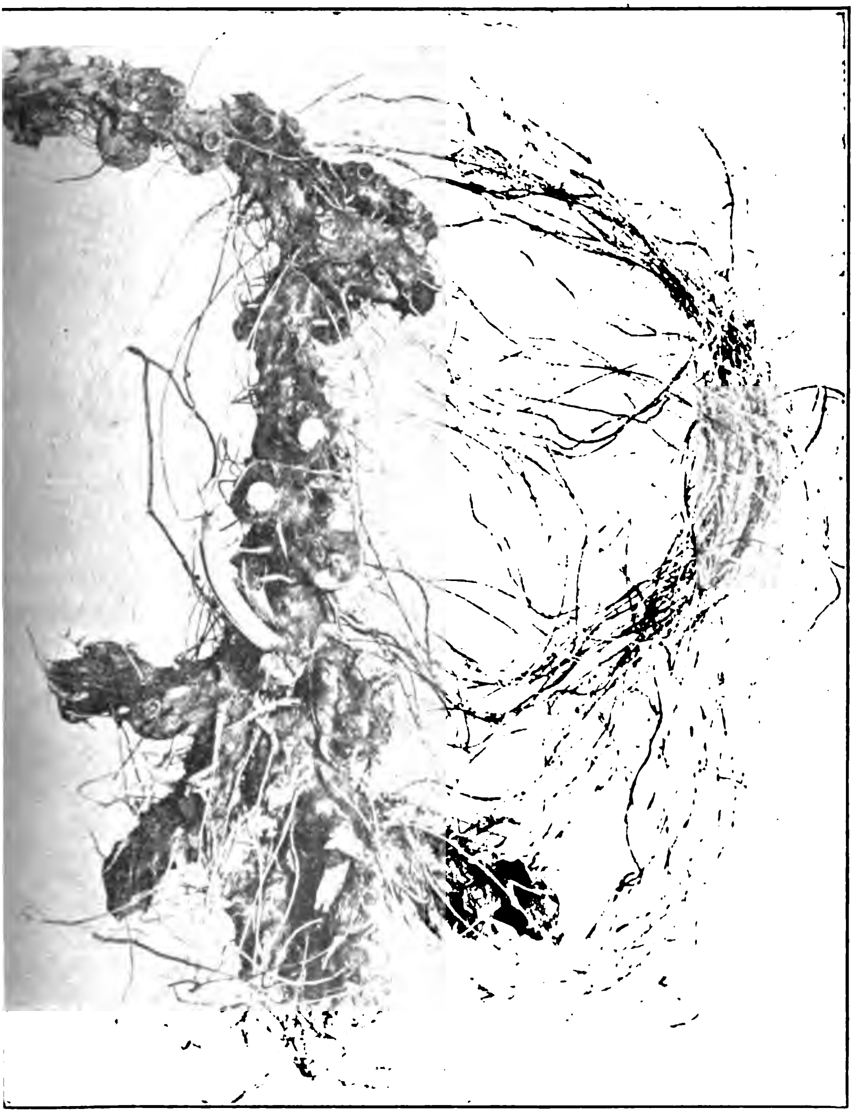

FIG. 8.—Rhizome of *Dioscorea glauca*. Typical drug from South Portsmouth, Greenup Co., Ky., collected by John Butler. (Two-thirds natural size.)

Department of Agriculture: Colicroot, chinaroot, devil's-bones (North Carolina); hobs-grub (Tennessee); rattlebox, cramproot (Kentucky).

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 190.

B. T. GALLOWAY, *Chief of Bureau.*

ORCHARD GREEN-MANURE CROPS IN CALIFORNIA.

NOV [illegible] 1910

BY

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SCIENTIFIC ASSISTANT, OFFICE OF FORAGE-CROP
INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 2, 1910.

Sir: I have the honor to transmit and to recommend for publication e accompanying manuscript, entitled "Orchard Green-Manure Crops California," by Mr. Roland McKee, Scientific Assistant in the fice of Forage-Crop Investigations, and recommend its publication Bulletin No. 190 of the Bureau series.

Leguminous cover crops are now extensively used in California rus orchards, but only to a slight extent in deciduous orchards. ving to peculiar conditions certain legumes are especially adapted use in that State, while their usefulness elsewhere is limited.

The results presented in this bulletin are based on the investigans that have been conducted at Chico, Cal., and in cooperation th many orchardists for the past five years.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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RCHARD GREEN-MANURE CROPS IN CALIFORNIA.

INTRODUCTION.

The use of green-manure crops for the maintenance of soil fertility s one of the oldest of agricultural practices. In California such rops have been used in a limited way for a long time, yet it is only vithin recent years that their practical value has become fully recognized. The growing of these crops has attained its greatest developnent in the citrus orchards of the southern part of the State, where hey have been longest used.

As far back as the early nineties some of the more progressive rchardists were beginning to realize the necessity of some such pracice as green manuring and to this end utilized the natural growth f bur clover and other weeds, such as alfilaria,[a] brome-grasses, etc. The Canada field pea was the first of the legumes to be used extenively as a green-manure crop, and by 1900 it was being quite generally grown in the citrus orchards of the southern part of the State. Common vetch and bur clover were also being utilized at this time.

In many parts of California, green-manure crops have not been used to any extent, but not entirely without reason. That their use can be made much more general than at present is quite certain, and as their value is more fully appreciated and their adaptation to the various sections demonstrated their use will be proportionately increased.

For a number of years the Bureau of Plant Industry has been working to secure better crops for green manuring than the ones now used and to aid in the demonstration of the adaptability of the ones now being grown. The Agricultural Experiment Station of the University of California has also done extensive work in demonstrating the value of various green-manure crops in that State.

In California the work of the Bureau of Plant Industry has been carried on in cooperation with orchardists and farmers throughout the various sections and at the United States Plant Introduction Garden at Chico, where extensive tests have been made. This work has clearly indicated the superiority of certain crops over others and their adaptation for varying purposes and conditions.

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[a] Known also as alfilerilla and pin-grass.

THE ORCHARD DISTRICTS OF CALIFORNIA.

The orchard districts of California so far as green-manure crops are concerned at once divide themselves into the citrus and the deciduous fruit districts. These are again readily divided into the northern and southern citrus districts and the irrigated and nonirrigated deciduous sections.

The two citrus districts have a definite geographical distinction, while with the deciduous orchards water is the differentiating factor, without reference to any geographical distinction. The citrus districts are quite definite in area. The southern district is confined to what is known as southern California proper and includes the territory south of the Sierra Madre Mountains and north along the coast to Santa Barbara. The northern district includes a narrow strip on the east side of the San Joaquin Valley from some distance south of Porterville to Lemoncove, Tulare County, on the north; a similar but smaller area in Fresno County; a small area in the Sacramento Valley, centering about Oroville and Palermo; and various small areas in other parts of the valleys and foothills.

Conditions with regard to water, soil, climatic or seasonal variations, etc., are quite different in these various sections, and the plant best suited to a certain area must be carefully considered in determining the probability of success with a green-manure crop. Practices satisfactory in one locality may be unsuited to another, and the crop best adapted to one section may not be adapted to another.

SOUTHERN CITRUS SECTION.

The seasonal conditions of the southern citrus section are such as to make this the most favorable part of the State for growing green-manure crops. The locality and climatic conditions are such that these crops are practically never injured by frosts, and the mild winters favor vegetative growth at that time of the year.

In contrast with the deciduous sections, where there is usually a heavy rainfall, here the rainfall is usually light. However, as irrigation is given throughout the dry season the conditions are favorable to the sowing of a green-manure crop early in the fall, thus giving sufficient time for considerable growth before the cold weather of winter.

The soils vary considerably in composition and mechanical texture, but as a general rule are of such a nature as to permit working at almost any time during the winter, except after heavy rains, thus favoring the turning under of a green-manure crop. While some soils in this section are a rich loam and contain considerable organic matter, as a rule they are quite deficient in this respect. That green manures need to be more extensively used is evident.

NORTHERN CITRUS SECTION.

The northern citrus section, as previously stated, comprises a small egion in the San Joaquin Valley, centering about Porterville and Exeter, and a smaller section in the Sacramento Valley, centering about Oroville and Palermo, besides small areas in various parts of he valleys and foothills of the State. The conditions in this district differ very much from the conditions in the southern California disrict, and in these differences is found the reason why green-manure rops have been but little used.

The seasonal conditions at the north while favorable to the growth of green-manure crops are less favorable for their handling. The ainy season is quite definite, extending through January and Febuary, and sometimes into March. The soil, which is heavy, dries out lowly during the winter season, often making it impossible to get nto the orchard to turn under a crop at the proper time. Thus, when he season for turning under is delayed, a heavy vegetative growth is objectionable in that it makes the land hard to work and at the same ime by shading prevents it from drying out to allow of cultivation as early as otherwise would be the case. The soils throughout the northern district are with few exceptions of the very heavy nature eferred to, and for this reason a heavy vegetative growth is often a hindrance to proper handling. While the immediate effects of a green-manure crop may be undesirable, there is but little question hat these lands need to be made lighter by the addition of humus, and results that appear at the time as unfavorable can well be tolerated when the ultimate effect will be an improved condition.

Green manures have been used but little in the northern citrus section. However, the results from a few plantings, together with the experimental work done, clearly show that by early seeding a good green-manure crop can be grown and in most cases can be profitably used.

DECIDUOUS ORCHARD SECTIONS.

While the deciduous orchards are scattered throughout the State of California they are largely in the northern part and are mostly located on the fertile lands of the various river valleys and the low foothills. Green-manure crops have not been used to any extent in these orchards, and practically the only thing approaching such a crop is the volunteer growth of bur clover, which is usually sufficient by the time the orchards are plowed in the spring to yield considerable humus.

The problem of growing a green-manure crop in deciduous orchards is quite different from that of growing the same crop in citrus orchards. This difference lies principally in the fact that the former are not irrigated, or if water is applied it is early in the summer, and not in the fall when it could be utilized in starting the crop.

Winter rains must be depended upon to germinate seed sown in the fall, and only in the most favorable seasons are they early enough to allow much growth before cold weather. When the first rains come late, but little growth is made by fall-sown seed until the warmer weather of the latter part of winter or early spring. Thus, only in the most favorable years will the growth be sufficiently early to allow its utilization for green manure. Where water is available for fall irrigation the question ceases to be one of the possibility of growing a good green-manure crop and becomes one of the returns justifying the expense.

CONDITIONS UNDER WHICH GREEN-MANURE CROPS SHOULD NOT BE USED.

There are some sections in which green-manure crops can be grown satisfactorily, but their utility nevertheless seems questionable. This is especially true in lemon orchards having a very heavy soil, and to a less degree in orange orchards. By a heavy soil is not meant a heavy loam, but an adobe or a soil approaching that texture. On such soils the discontinuance of cultivation which is necessitated by the growing of a green-manure crop allows the soil to become quite hard and packed, thus permitting very imperfect aeration. This is a most undesirable soil condition to maintain during a period of several months, and its injurious effects may be seen in the unthrifty appearance of the trees. Where this effect is very marked it is undoubtedly best not to use a green manure, but to use stable manure instead, if such is available.

In the Porterville and Oroville citrus districts, where the soils are quite generally of a heavy type, the foregoing statement does not apply as definitely as in the southern California districts. This is due to seasonal differences. The trees in the two former sections have a more nearly dormant period of growth during the early winter than those in the latter, in which case the effect of noncultivation is not so marked. Where on account of heavy soils it is not advisable to grow a green-manure crop, stable manure, if available, should be used in lightening the soil.

QUALITIES DESIRABLE IN A GREEN-MANURE CROP.

No one plant possesses all the desirable qualities of an ideal green-manure crop. However, in the various crops used for such purposes, practically all the desirable qualities are represented, though varying in degree. The conditions under which a green manure is to be grown determine to some extent whether a certain quality is esirable or objectionable and must be taken into consideration in electing the best crop to grow.

A green-manure crop should be a legume wherever possible, in rder to obtain the addition of nitrogen to the soil. It is also neces- ary that a good growth be made, in order to have a large quantity of rganic matter to turn under and incorporate. with the soil. Along ith good growth should be a heavy development of nodules on the ots, as this is believed to indicate great ability to fix atmospheric itrogen.

The quality of being able to stand trampling with a minimum of njury is very important where the crop will be subject to such injury, s is the case in citrus orchards where the picking of fruit takes lace while the green-manure crop is yet growing. Uprightness and ontwining stems are also desirable where an ordinary moldboard low is depended upon for turning under the crop. However, if a isk plow is used or the crop is worked in with an ordinary disk arrow, this does not make so much difference, and where the growth not allowed to become too rank little difficulty is experienced in lowing it under.

The texture of the stem should be such as to decompose readily. ractically all crops, however, if turned under at the right stage of rowth decay readily. Thus, the question of decomposition is one of urning under the crop at the right time rather than one of selecting crop that will decay readily.

That the cost of a green manure may not be too great, it is neces- ary that the price of seed be reasonable as compared with the results o be obtained.

METHODS OF HANDLING GREEN-MANURE CROPS.

The methods of handling green-manure crops in California are uite similar throughout the various sections. However, some vari- tion in practice exists among orchardists in the same neighborhood, as ell as among those of different localities.

The following methods are practiced in the citrus and walnut rchards of the southern part of the State, where green manures have een most generally grown.

PREPARATION OF THE LAND.

Since clean culture is practiced throughout the year in citrus and alnut orchards except when a green-manure crop is being grown, he land can be prepared at any time for the seeding of such a crop.

The general practice is to prepare the land for seeding by plowing r disking and harrowing immediately after an irrigation. This puts he land in good condition for the seeding.

SEEDING.

The most successful growers of green-manure crops sow vetch and bur clover in the first half of September, and peas during the latter half of the same month. Early seeding is being much more generally practiced now than it was a few years ago, when the greater part of the crop was sown in October. The time of irrigation of an orchard determines to some extent when a green-manure crop shall be sown, as water is not always available at the time desired. However, when water is available the time mentioned is that most generally favored for irrigation.

The seed is sown either drilled or broadcast and harrowed in.

IRRIGATION.

After the seed is sown and before it germinates, the land is prepared for fall or winter irrigation if necessary. The furrow method is [illegible] one most commonly used. This consists in making a number [illegible] shallow furrows between the rows in the direction the water [illegible] flow, the method varying in different sections and with the lay [illegible] land.

The basin method is used to quite an extent in the walnut orchards of the southern part of the State and in the orchards of the S[illegible] Clara Valley.[a]

Nothing further is done, with the exception of irrigating if [illegible] sary, until the crop is ready to turn under. When a crop is sown [illegible] September it can be plowed under during February.

TURNING UNDER A GREEN-MANURE CROP.

In turning under a green-manure crop the common moldboard plow (see fig. 1), the disk plow, or the disk harrow is used. In [illegible] the first a sharp colter is attached, and where the vine growth [illegible] heavy a chain is also used. Sometimes the land is run over [illegible] with a disk harrow before plowing. This enables a heavy growth to be more completely turned under. During the past few years the disk plow has been very generally used, and for turning under a heavy vine growth it works more satisfactorily than the moldboard plow.

After plowing under a green-manure crop the land is harrowed, and as the crop decays cultivation is given. This at first is shallow, so as not to bring the vines to the surface, but later a deeper cultivation is given.

In sections having a very open soil or a sandy loam the disk harrow has been used very successfully in turning under a green-manure crop. The use of this harrow has been taken up with the idea that fewer surface-feeding roots of the trees are disturbed by its use than the case with the plow, for which reason it is thought by many to e more desirable. In working a green-manure crop into the soil ith a disk harrow, four diskings are usually required, each disking, here the planting of the orchard will permit, being made at an angle ith the previous one. On the heavier soils the disk harrow does not ork so well and the plow is used almost entirely.

---

[a] See Bulletin 145, Office of Experiment Stations, pp. 46-50.

After turning under a green manure the land is kept well cultivated e remainder of the year.

For obtaining the best results a green-manure crop should be rned under early enough in the season to allow perfect decomposiion. In orchards this can be quite definitely designated, as the urning under should take place before the trees start growth in the pring. This means, for citrus orchards in southern California, not ter than February. In northern California the season is of necesity a little later on account of the generally wet condition of the soil t that time. Where the factors relating to other crops and a season avorable to decomposition do not have to be taken into consideraion, it perhaps is safe to say that to obtain the best results most egumes should be turned under about the time the first pods form, r a little earlier.

G. 1.—View in a California orange grove, showing the method employed in plowing under a green-manure crop.

INOCULATION.

The question is often asked whether it is not advisable to inoculat
seed to be sown on land that has not previously grown that crop. I
California it has been found that the bacteria necessary to nodul
formation on the more common leguminous crops are present in mos
soils. The first seeding may not, however, be as abundantly inoc
lated as desired, and in some sections the bacteria essential to certai
crops seem to be entirely lacking in the soil.

In northern California it has been observed that horse beans ar
not inoculated the first year they are grown on soil that has not pr

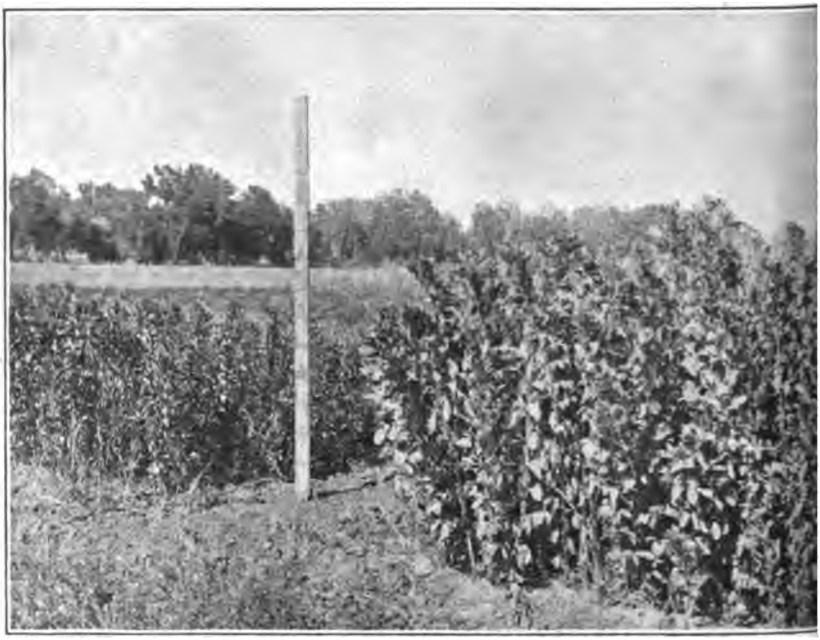

FIG. 2.—Experimental plats of horse beans at Chico, Cal., showing the striking superiority of the nod
plants.

viously grown this crop. (See fig. 2.) Thus, to obtain the be
results, it is necessary to inoculate the crop the first year. The di
ference between an inoculated and an uninoculated crop of hor
beans in the Sacramento Valley is very marked and is practical
the difference between success and failure. In southern Californ
this crop does not require artificial inoculation, the soil being inoc
lated.

In the inoculation of horse beans the surest results are obtained b
securing soil from an inoculated plat or field and mixing this wi
the seed at the time of seeding. In this way but little soil will b
required to inoculate a large area, and practically no extra time

or is necessary. The inoculation of this crop may also be attained spreading inoculated soil over the field at the time of seeding and rking it in with the seed, or the seed may be inoculated with pure ltures of the bacteria which form nodules on the roots of this plant. ch cultures have been distributed by this Department for several ars, and the results obtained from their use have been favorable in ny cases.

COMMERCIAL FERTILIZERS.

In the citrus orchards of California commercial fertilizers are quite nerally applied, while in few deciduous orchards are fertilizers used any form. Where fertilizers are used they are usually applied in nnection with a green-manure crop.

The value of a green-manure crop is largely due to the part it plays liberating plant food in the soil. In the decay of organic matter d the giving off of carbonic-acid gas, the action on phosphorus and tassium compounds is such as to make them more available as ant food. Vegetable acids, which are always more or less present th a green-manure crop, also aid in liberating plant food. Thus, ments present in a soil but not available as plant food may be de so by the use of a green manure.[a]

From the facts just stated it will be readily seen that a green-nure crop may serve a useful purpose when used in connection h commercial fertilizers, especially where the various plant-food ments are only partially available in the soil.

INTER GREEN-MANURE CROPS NOW USED IN CALIFORNIA ORCHARDS.

The green-manure crops now used in California, in the order of ir importance, are as follows: Common vetch, Canada field peas, clover, fenugreek, hairy vetch, and Indian melilot.

Common vetch and field peas are by far the most extensively nted, while hairy vetch and melilot are very little used. Bur over and fenugreek are used to but a limited extent, although they e of considerable importance.

COMMON VETCH.

The common or spring vetch (*Vicia sativa*) is the most exten-ely grown green-manure crop in California. It is being grown roughout the orchard sections wherever green-manure crops are ing used at all (see fig. 3). It is adapted to quite varied con-tions and succeeds in all sections of the State. In the coast sec-ns, as well as inland, it makes a good growth and does well on both e light and the heavy soils.

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[a] See E. W. Hilgard, Soils, pp. 19–21, 63, 126, and 394–396.

The qualities of common vetch are such as to make it well adapted for green-manure purposes, especially in citrus orchards, and orchardists in general are growing it in preference to field peas, which were largely grown a few years since.

Common vetch makes a vinelike growth similar to that of peas, but the vines are less succulent and so are able to stand considerable hard usage without much injury. Thus, in orchards when picking fruit and doing other work, the trampling which is unavoidable interferes but little with the growth of the vetch. The root system, which is quite extensive, lies largely near the surface and ordinarily is well covered with nodules.

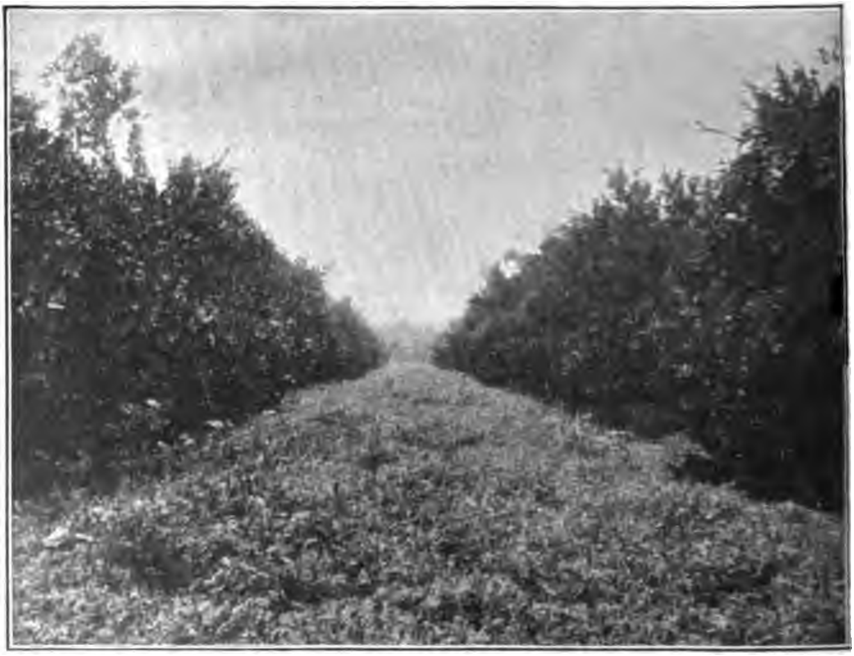

FIG. 3.—View in an orange orchard in southern California, showing common vetch grown as a green-manure crop.

When used for a green-manure in southern California common vetch is usually sown during September and the first half of October. However, better results are being secured with the earlier seedings, and in most years to obtain the best results it is quite essential that the crop be sown during the first half of September. When thus sown the plants make a good growth before cold weather and continue to grow during the winter. But if the seed is sown late and the plants have made but a small growth before the cold weather, they then make little or practically no growth until the warmer weather comes in the latter part of the winter.

In February, 1908, at Redlands, Cal., which is representative of the citrus sections, plantings of vetch made in September, 1907, were from 12 to 15 inches high and in a fine condition to turn under. Plantings made in October, 1907, from a month to six weeks later, were but 3 inches high. During the past season similar results were noted.

The rate of seeding varies from 40 to 60 pounds per acre. Forty pounds per acre has been more generally recommended, but the heavier seeding is giving much better crops and more than makes up for the difference in the cost of the seed.

Early as well as heavy seeding is quite commonly recognized by growers as necessary for obtaining the best results, and a deeper seeding has also been found essential where the plantings are early. In northern California under irrigation, vetches should be sown about the first of October. They will then make sufficient growth to be turned under in February or March. This later season of planting in the northern part of the State is desirable in both citrus and deciduous orchards on account of the heavy winter rainfall, which does not permit turning under the crop as early as in the southern section. Later planting in the deciduous-orchard sections is also desirable on account of the possible injury from frosts when an early succulent growth is made, as would be the case with earlier plantings.

Experiments and observations have shown that vetch will make but little growth by February or March when sown in the fall without irrigation.

CANADA FIELD PEAS.

The field pea was among the first crops tried in California for green manuring and was the first one extensively used for this purpose. Its early use was partly due to the fact that seed was readily obtainable. At the present time it still holds a prominent place as a green-manure crop, and next to common vetch is most extensively used (see fig. 4).

Like the common vetch the field pea is adapted to varied conditions and has succeeded wherever green-manure crops have been grown. For making a growth during cool weather there is no other crop known that equals it; but it has other characteristics that make it less desirable for green manuring, especially in citrus orchards.

The root system of the field pea, which is very extensive, consists of a central or main taproot from which radiate the many finer laterals. The roots extend quite deep, and for this reason the crop is favored by many orchardists for breaking up "plow sole."

The vines, which are succulent and tender, are greatly damaged by the trampling necessitated during the harvesting of most citrus fruits; and on account of their making so much new growth during cold weather they are often severely injured by frost. Usually as the plants approach maturity the lower portions of the stems become dry and wiry, making the turning under difficult.

Aphids, or plant lice, are very fond of peas and nearly every year their attacks occasion considerable damage. In the coast sections or those having more humid conditions, the crops also suffer severely from the attacks of mildew. Inland, however, there has been but little injury from this cause.

While field peas are in some ways objectionable they also have certain qualities that make them serve special purposes. Their ability to stand late fall planting and still produce a fair winter growth makes them especially valuable for such use when for any reason an earlier planting of other crops has not been accomplished, but if sown late only a very ordinary crop can be expected. While peas may be planted from the middle of September to the end of November, in southern California the best results are secured from September plantings. In the northern part of the State the middle of October is better for planting because the winter rains prevent the crop from being turned under until later in the winter. When planted early, peas in the north are also likely to suffer more severely from winter frosts.

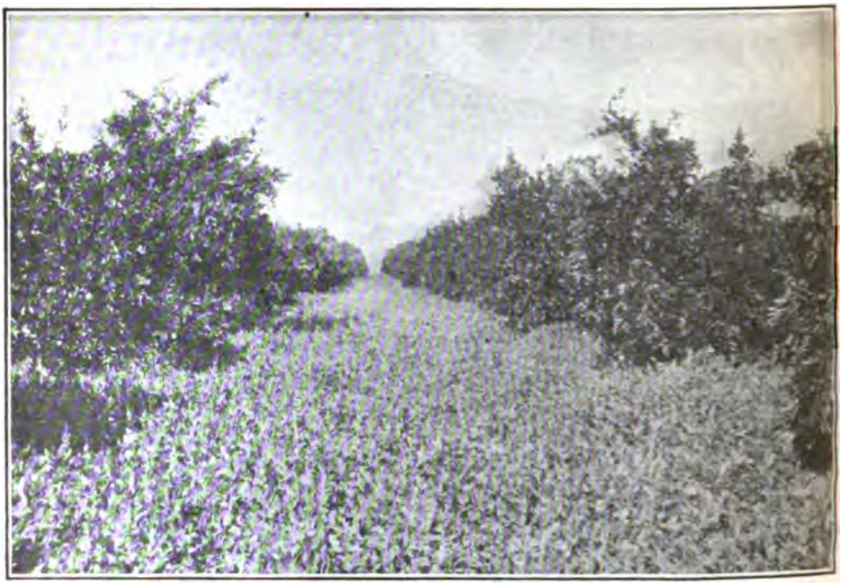

FIG. 4.—View in an orange orchard in southern California, showing Canada field peas grown as a green-manure crop.

Seventy pounds of seed per acre is the usual rate of seeding. This in some cases gives a very good crop but a thin stand, and therefore a light yield has been very noticeable in all orchard sections. At least 80 pounds of seed per acre should be used, and unless seeding conditions are very favorable more rather than less is recommended.

During the past few winters the general crops of field peas and vetch throughout the orchard sections of California have shown that peas make a stronger individual plant growth than vetch, but do not make as heavy a yield of green manure. When sown during the latter part of September the peas have made a growth of from 24 to 36 inches, while common vetch made from 15 to 18 inches. This is representative of the usual comparative stem growth of the two crops. In the citrus orchards of southern California peas should be turned under early in February. and in the northern part of the State during the latter part of February or the first of March.

BUR CLOVER.

There are a number of kinds of bur clover, of which only two are yet much grown in California, namely, the common or toothed bur clover (*Medicago hispida denticulata*) and the spotted bur clover (*Medicago arabica*). The toothed bur clover is the one most commonly seen, being thoroughly naturalized, but the spotted bur clover, though less abundant, grows equally well. It differs from common bur clover in having a brown spot on each leaflet and longer and softer spines on the burs.

Bur clover makes a decumbent growth, the stems being rather small and quite succulent when young, but it withstands considerable trampling. The roots are shallow but numerous and usually have many nodules. The crop has been grown to quite an extent for green manure, but on account of its not making a good early-winter growth its use will always be limited. In orchards where bur clover has been once planted it will spring up for several years. This is due to the hard seeds that do not germinate the first year. In the citrus orchards of southern California bur clover is sown at the same time as vetch, which is during September and early October. To obtain the best results, seeding as early as possible in September is advised. Twenty pounds of seed (hulled) per acre should be used, care being taken to plant shallow, as deeply covered seed will not germinate but will hold over in the soil. The sowing of seed in the bur is not recommended, because the bur delays germination and occasions very uneven stands, to say nothing of the greater difficulty in sowing. However, there is no longer need of using seed in the bur, as clean seed can be secured in quantity from western seedsmen.

For use in deciduous orchards bur clover is of considerable importance and if properly handled will serve a very useful purpose. At the present time it is utilized only where it volunteers as a weed and can be turned under at the regular spring plowing of the orchar

On account of the light growth usually made by a green-manure crop sown in the fall without irrigation, the expense of seeding a crop each year in this way is hardly justified. Through the use of bur clover this objection can be overcome by allowing the crop to reseed itself from year to year. In this way with a little care bur clover can be maintained in an orchard at small expense. If an occasional late season prevents the crop from ripening its seed before the orchard must be plowed, narrow strips can be left between the rows to mature, and in this way reseeding be accomplished. The fact that the seeds of bur clover do not all germinate the first year but hold over in the soil until the second or third year, or even longer, lends to the ease of maintaining the stand.

Bur clover is at present most commonly introduced and maintained in orchards by the use of manure from old sheep corrals, which usually contains large quantities of the seed.

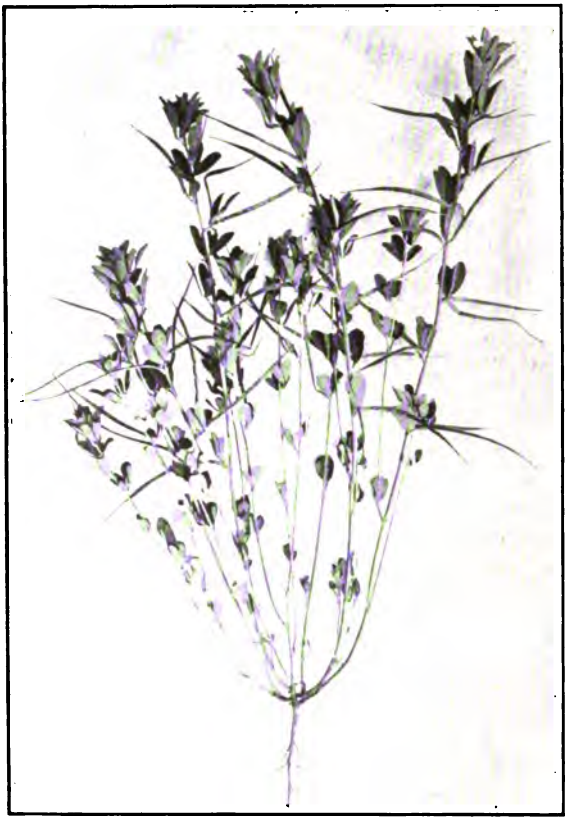

FIG. 5.—An individual plant of fenugreek, showing its characteristics.

FENUGREEK.

Fenugreek (*Trigonella foenum-graecum*) is an upright-growing plant having a central stem which is more or less branched. A somewhat open top is formed when fenugreek is grown as an individual plant (see fig. 5). When grown in plats with little chance for individual development, but few branches are formed. The plants attain a height of 20 to 30 inches. The leaves, of which there is a medium number, are trifoliate, with cuneate or obovate thickish leaflets. The seeds, which are borne in long, pointed pods, are quite small (one or two lines long) and of a brownish-yellow color. The pods dehisce, or break open, tardily, making the crop one that can be handled easily for seed.

ADAPTATION.

Fenugreek is grown in quantity in California only in Ventura and Orange counties. The recognition of its value as a green-manure crop dates back to 1903, it having been distributed the previous year by the California experiment station. Since that time its use has gradually increased, and while it is only in Orange and Ventura counties that it has been used as a regular crop it has been tested and grown in a small way in all the citrus sections of the State (see fig. 6).

From tests and observations made during the past three years it seems quite evident that fenugreek is best adapted to the citrus sections of the State having the immediate coast influences. The climatic conditions of such localities are very favorable for fenugreek, and it is therefore in those sections that it has attained its best development. In sections farther from the coast, such as at Riverside and Redlands, and in the interior valleys of the State, quite good crops have been grown, but in such localities the crop is more exacting in its requirements as to time of planting, etc.

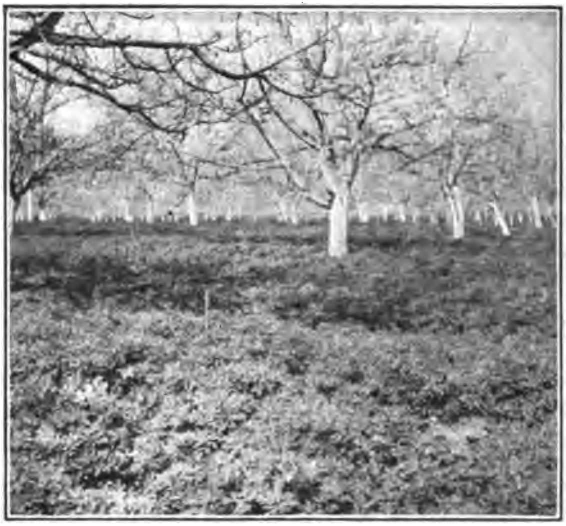

FIG. 6.—View in a walnut orchard in Orange County, California, showing fenugreek grown as a green-manure crop.

COMPARATIVE VALUE.

In comparative tests made at Redlands, Cal., fenugreek sown October 7, 1907, by the middle of February, 1908, had attained a height of 10 inches. Common vetch made but 6 inches of growth in the same time. At Pomona, Cal., fenugreek sown November 4, 1907, by the middle of February, 1908, had made a growth of 18 to 24 inches. Common vetch in comparison made but 8 inches of growth during the same time. At Chico, in northern California, fenugreek sown October 5, 1908, with irrigation, by the first of March, 1909, had made a growth of 12 to 15 inches, and of 16 to 20 inches by the middle of March. In other tests the fenugreek did not make so good a showing, yet wherever sown early it has done quite well.

As to the quantity of green manure produced by fenugreek in comparison with other crops there are but limited data. At Santa Paula, Cal., weights of vetch and fenugreek were taken the middle of February, 1909, to determine the quantity of green manure produced. The plants growing in the space between four trees were cut and weighed green, and the yield per acre was computed from these weights. The fenugreek yielded 11,745 pounds per acre solid area, or 8,432 pounds orchard area, while the common vetch yielded 19,140 pounds per acre solid area, or 13,742 pounds orchard area. However, these figures do not justly represent the comparative yield of organic matter, as the moisture content of the vetch was undoubtedly much greater than that of the fenugreek, and the yield of dry matter of the two crops would have been much more nearly equal than is indicated by the figures given. At Chico, in northern California, fenugreek weighed green March 16, 1909, yielded at the rate of 13,721 pounds per acre. This was from plantings made October 5, 1908. In comparison, at Chico, common vetch produced but 2,831 pounds per acre.

Considering the convenience and cost of handling, fenugreek is superior to any other green-manure crop now being used. The upright habit of the plant makes the crop easy to turn under. The roots have many nodules and form a system similar to that of the field pea.

Fenugreek is especially desirable for an orchard green-manure crop, owing to the fact that no insect pests seem to be harbored by it. This point has been especially noticeable in sections where the army worm, harbored in such crops as vetch, bur clover, and field peas, has done considerable damage to fruit. During the season of 1907, orchards in which fenugreek was being grown were noted as being free from the army worm, while other orchards in the same section were quite badly infested.

PLANTING.

No special preparation of the land is necessary for planting fenugreek. A seed bed such as is desirable for ordinary field crops is all that is required. The best time for seeding varies somewhat in the different parts of the State. For a winter green-manure crop in southern California, in sections away from the coast, such as Pomona and Redlands, plantings should be made as early in September as possible. In sections near the coast plantings may be made later with good results, but September planting is to be advised. In northern California plantings for green manure should be made the first of October.

Fenugreek does best on a good, deep loamy soil, but such a soil is not necessary for success, as the plant does quite well on a gravelly or a sandy soil. It is not adapted, however, to a soil that will become hard, like heavy clay or adobe. The crop should be sown either broadcast or in close drills. Thirty pounds of seed per acre is necessary for a green-manure crop, while less is best for a seed crop. Care should be taken not to plant the seed too deep.

SEED PRODUCTION.

The fenugreek seed handled by American seedsmen is almost entirely imported. The demand for it has been so slight that only small stocks are handled. The imported seed comes from the Mediterranean countries, chiefly from Egypt and Palestine. The seed of fenugreek used in the orchard green-manure work in California is grown almost entirely in Orange and Ventura counties, in which localities a good crop of fine seed can be produced.

Possibly the only sections where fenugreek can be grown profitably as a seed crop are where the winters are very mild, having at most light frosts, so that with late fall seeding there will be a sufficient growth made during the winter months. An ordinary grain drill is the best implement to use in seeding. From 15 to 20 pounds of seed per acre are sufficient. After seeding, nothing is done with the crop until it is harvested. In the interior valleys an irrigation at the time of seeding is necessary.

The crop can be cut with an ordinary mower, and after a short time should be raked into windrows. Here it should be allowed to cure for several days before thrashing, which can be done with an ordinary thrashing machine. In so far as possible the crop should be taken from the windrows in the early morning, there being less shattering of the seed when handled at this time. The pods when very dry drop from the stem and dehisce, or break open slightly, although the loss of seed from this cause is not great.

The quantity of seed produced per acre varies as with any other crop, and while there are few definite figures as to yields, in Ventura and Orange counties, where the best fenugreek seed crops are produced, probably 1,500 pounds per acre is an average yield. At Chico, in northern California, plantings in $\frac{1}{20}$-acre plats yielded at the rate of 490 pounds of seed per acre, while one smaller plat yielded at the rate of 1,315 pounds per acre. The Chico plantings were made with irrigation the first half of October, 1908. The crop was harvested the 1st of June, 1909.

HAIRY VETCH.

The hairy or winter vetch (*Vicia villosa*) is not so well adapted for green-manure purposes as is the common vetch, and it has not been used except in a very limited way. Under California conditions it makes less growth during the winter season than the common vetch, and this has prevented its larger use for green manuring. Extensive experimental tests in comparison with common vetch, as well as practical tests made by orchardists, show the same results.

While hairy vetch does not make a good winter growth, when the warmer weather of the latter part of winter and early spring comes, it makes a very vigorous start and, if left to develop fully, a heavier growth than common vetch. It also stands more dry weather without injury, and where a late spring crop is wanted it is very desirable. The handling of the crop is the same as with common vetch. From 45 to 50 pounds of seed per acre should be used in seeding.

INDIAN MELILOT.

Indian melilot (*Melilotus indica*) is quite common in waste places throughout the orchard sections of southern California and for a number of years has received some attention as a green-manure crop. However, it has never been used except in a very limited or experimental way, and this experience indicates that it has but very little value in orchard work in California.

The winter growth of melilot is about like that of bur clover, and, like that crop, its best growth is not made until too late in the winter to be turned under in February. The only place in California where melilot seems likely to prove at all valuable is on the very sandy soils, to which it is quite well adapted and on which it is often hard to get a stand of other green-manure crops.

SUMMER GREEN-MANURE CROPS.

The question is sometimes asked whether it is advisable to grow a summer green-manure crop as well as a winter crop, thus enabling one to add two crops a year to the soil instead of one. Where water for irrigation is available there is no difficulty in doing this. However, the practice is not to be advised except under very exceptional conditions. The enormous quantity of water used by a green-manure crop in its growth makes it decidedly objectionable for summer use in an orchard, where all the water available is usually needed for the orchard crop.

The growing of a summer green-manure crop also necessitates the discontinuance of cultivation of the soil, which except on the most open soils would be more or less detrimental if continued for a long period. There may be instances, however, where it is desirable to build a soil up as rapidly as possible. In such cases a summer green-manure crop may be used to advantage. For this purpose the Whippoorwill variety of cowpea has been found the best of any crop tested.

RESULTS OF GREEN MANURING IN CALIFORNIA.

There have been no definite tests made in California to determine the results in an increased yield of fruit or improved quality of the same from the use of green manures. The only evidence available is that of general observation and the experience of the orchardists.

While orchardists differ to some extent in conclusions, they generally are favorable to the practice, as its continued and growing use attests. Careful observations also show the beneficial results of green-manure crops in a more thrifty appearance of the trees, an improved condition of the soil, and a better quality of the fruit. The belief is quite general that the yield, also, is increased. Orchards in which a few years ago there were unthrifty trees with yellowish-colored leaves now, after several years' use of green-manure crops, show a decided improvement in color and general appearance. The work of the California experiment station has demonstrated that gummosis of citrus trees is brought on by unfavorable soil conditions and that in remedying such conditions green manures serve a very useful purpose.[a] Orchards in which green manures have been used for a long time are but little affected by this disease.

The improved condition of the soil when green manures have been used for some time has been readily noticeable to those handling an orchard. The heavier soils have become quite open and friable and the sandier soils more loamy. Beneficial results in the conserving of rainfall and the prevention of washing of the soil have also been very apparent. Most soils that wash badly do so because they are deficient in organic matter. Green manuring, by the improvement of the mechanical condition of the soil, not only prevents washing, but the presence of the growing crop on the land prevents gullying during the rainy season. This is of particular importance on sloping lands.

RESULTS OF TESTS WITH VARIOUS LEGUMES.

From the fact that the addition of humus to the soil is one of the main objects in using a green manure, it necessarily follows that, other things being equal, the crop producing the heaviest vegetative growth is the most desirable. To determine the comparative amount of vegetative growth made by various crops the green weight per acre has been determined, as shown in Tables I, II, and III. However, these figures can be taken only as indicating in a general way the amount of organic matter returned to the soil, as no corrections were made for the varying moisture content of the different crops.

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[a] Bulletin 200, California Agricultural Experiment Station. 1908.

In Table II the weight of the green material produced per acre is presented, together with the weight of the same when dry. The green material was weighed at the time of cutting, and for estimates of the yield of dry matter was weighed again in thirty days. During this period the various crops had become nearly dry, but undoubtedly the moisture content, even at this time, would vary to some extent, although not nearly so much as in the green state.

That the yield of green material as shown by its weight may be misleading without proper correction for the moisture it contains is shown in Table II in the case of the two lots of black-purple vetch. The first lot was quite succulent at the time of cutting, and consequently was very heavy in the green state, while the other was a little older and less succulent, and so was much lighter. The latter did not show the heavy loss in drying that the former did, however, and thus the difference in the amount of organic matter of the two is not nearly so great as the difference in the weights of the green matter would indicate. In this connection it should also be noted that varying yields are often due to a difference in the stands rather than to differences in the growth of the crop. In the comparative data presented in the tables this has been reduced to a minimum by selecting for this purpose crops with as nearly uniform stands as possible.

From all data available it seems clear that of the commonly grown green-manure crops, vetch, peas, bur clover, and fenugreek, the vetch returns the most organic matter to the soil and the peas the least. The light yield of peas is not due to a lack of stem growth, which on the contrary is always good, but to the generally poorer stand and more open habit of growth. Bur clover, while weighing heavy green, is very succulent when young, and when compared with an equal weight of green vetch represents much less organic matter. Fenugreek yields well, but not so much as vetch.

In securing the yield of green manure per acre, as presented in Table I, the plants growing on a plat 6 by 20 feet were cut and weighed green and the yield per acre computed from these weights. In Table II a plat 10 by 10 feet square of each crop was cut and weighed green and the yield per acre thus calculated. The same was weighed again in thirty days, as shown in the table, giving the yields of the dry matter. In Table III the weights shown were taken from crops being grown by orchardists during the winter of 1908–9 at the places mentioned in the table and are representative of these crops as grown under actual orchard conditions. To obtain the results the plants growing on a space between four trees were cut and the yield per acre calculated from such weights.

Table I.—*Growth of plants and weight per acre of green-manure crops sown with irrigation October 19, 1907, at Chico, Cal.*

Name.	Rate of seeding.	Height of plants, March 18, 1908.	Weight of green manure, March 28, 1908.
	Pounds.	*Inches.*	*Pounds.*
Black bitter vetch	130	26	32,056
	34	26	23,236
Black-purple vetch	56	30	24,042
	34	30	15,609
Woolly-podded vetch	17	28	18,876
Hairy vetch	56	15	11,616
Common vetch	39	12	7,623
Lathyrus sativus	56	16	19,239
Tangier pea	56	18	13,794
Field pea	159	26	15,944
Horse bean	164	28	10,890

Table II.—*Growth of plants and weight per acre of green-manure crops sown with irrigation October 5, 1908, at Chico, Cal.*

Name.	Rate of seeding.	Height of plants, March 15, 1909.	Weight of dry matter, March 16, 1909.	Weight of dry matter, April 16, 1909.	Proportion of dry to green matter.
	Pounds.	*Inches.*	*Pounds.*	*Pounds.*	*Per cent.*
Black-purple vetch	62	32-36	40,565	3,675	9.0
	45	36-40	14,374	2,321	16.8
Woolly-podded vetch	48	30-36	25,047	2,933	11.7
Black bitter vetch	76	20-22	27,660	3,776	13.6
	49	20-22	14,374	2,130	14.8
Horse bean	149	30-36	21,130	2,634	12.4
Fenugreek	29	16	13,721	1,783	12.9
Tangier pea	72	17	12,840	1,646	12.8
Bur clover	21	14-16	11,980	735	6.1
Hairy vetch	31	8-15	5,880	871	14.8
Common vetch	33	10-18	2,831	....	....

Table III.—*Weight of green-manure crops growing in orange orchards in California.*

Name.	Place.	Weight of green matter per acre.	Weight of green matter per 0.718 acre.[a]
		Pounds.	*Pounds.*
Tangier pea	Redlands	29,093	20,888
Common vetch	....do	13,578	9,749
Malva rotundifolia	....do	19,800	14,216
Bur clover	....do	16,347	11,737
Field pea	....do	7,260	5,212
Fenugreek	Santa Paula	11,745	8,432
Common vetch	....do	19,140	13,742

[a] This equals the part of an acre usually covered by a green-manure crop in an orchard.

PROMISING GREEN-MANURE CROPS.

As shown by Tables I and II, giving comparative yields, there are several plants very promising for green-manure purposes as compared with common vetch and field peas. The claim of superiority for these plants is largely due to their ability to make more growth during the cool weather of the winter, thus affording a heavier growth to be turned under. This is an especially strong point where it is desirable to turn the crop under as early as possible, as is the case in the citrus orchards of southern California. The plants referred to are the black-purple vetch, the black bitter vetch, the woolly-podded vetch, the horse bean, and the Tangier pea.

BLACK-PURPLE VETCH.

The black-purple vetch (*Vicia atropurpurea*) is one of the most promising green-manure crops tested for California. Its general appearance and habit of growth are about like those of the common vetch (fig. 7), although it is very distinct from that species. The superior value of black-purple vetch when compared with common vetch lies in its ability to make a much stronger growth during the cool weather of early winter. This, as noted elsewhere, is an especially desirable quality in a green manure to be turned under in February.

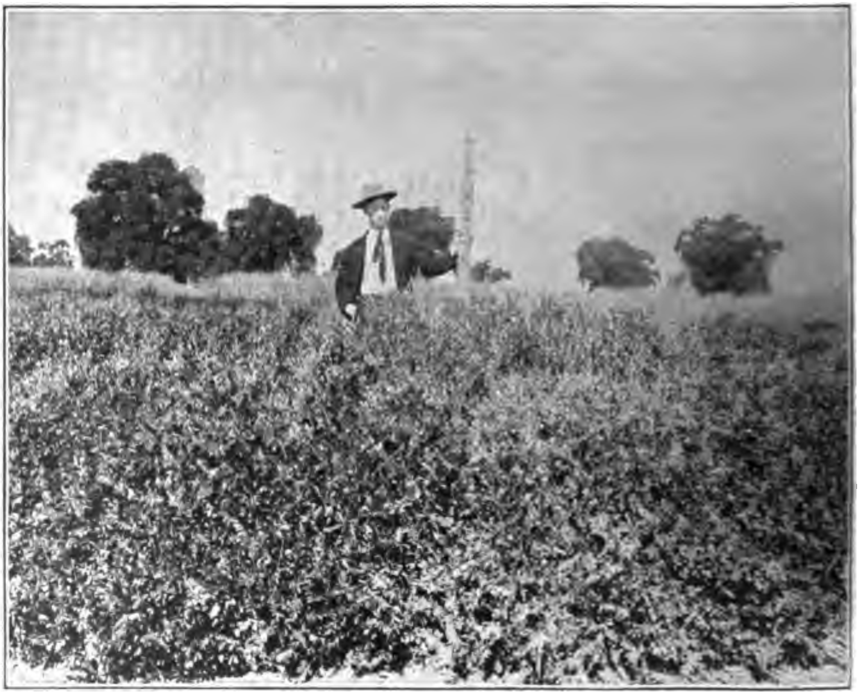

FIG. 7.—A field of black-purple vetch at Chico, Cal.

The root system of black-purple vetch, which is similar to that of common vetch, is well covered with medium large nodules. The stems, aside from making a strong growth, are of such a texture as to enable them to stand much trampling or other hard usage without injury.

The time and manner of seeding this crop are much the same as with common vetch. As the seed is a little smaller, however, a smaller quantity may be used in seeding. From 50 to 60 pounds per acre is advised.

BLACK BITTER VETCH.

Black bitter vetch (*Vicia ervilia*), another very promising green-manure crop for California, is different from most other vetches in that it is upright in its habit of growth, rather than vinelike. Like the black-purple vetch, it possesses the desirable quality of making a good growth during the cool weather of early winter and is much superior to common vetch in this respect. (See fig. 8.) In this connection it should be noted that different strains of this vetch have given different yields, so that some will doubtless be found superior to others.

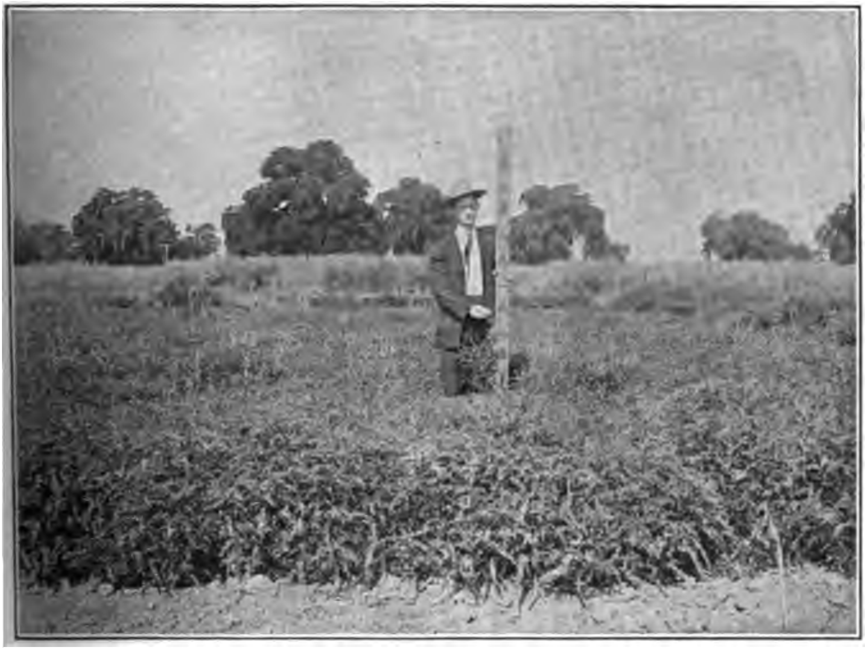

FIG. 8.—A field of black bitter vetch at Chico, Cal.

Its upright habit of growth makes this crop very easy to turn under with an ordinary moldboard plow. The viny growth of common vetch makes it objectionable to some orchardists. The root system, while quite well covered with nodules, is perhaps not so extensive as that of some of the other vetches. The plant has a more definite central root, or taproot, than common vetch, and the fibrous roots tend to penetrate more deeply. The seeding habits are much better than those of other vetches. The pods shatter but very little, which much facilitates the harvesting of the seed.

Black bitter vetch is grown very extensively in the Mediterranean region, where the seed is a commercial product. The fact that the seed of this plant can be imported at a reasonable cost makes it possible to supply the trade at once. On account of the plant branching but little it is necessary to use a slightly larger quantity of seed in seeding than with common vetch. Seventy pounds per acre is recommended. Aside from the quantity of seed per acre used, the crop should be handled like common vetch.

WOOLLY-PODDED VETCH.

Woolly-podded vetch (*Vicia dasycarpa*) resembles hairy vetch quite closely, both in appearance and in agricultural value.

In comparative tests the woolly-podded vetch has made a stronger growth during the cool weather of early winter than the common or the hairy vetch, but not so strong as the black-purple vetch or the black bitter vetch. As soon as the warmer weather of the latter part of winter comes it is one of the most vigorous growers and its ultimate yield is very heavy. Thus, while it will serve very well as a crop to be turned under in early winter its special value is for conditions where the crop can be allowed to remain a little later in the spring. For sowing without irrigation in deciduous orchards it may be of special value.

Woolly-podded vetch stands trampling well and for orchard use is in this respect equal, if not superior, to common vetch. The root system is about like that of common vetch and is well covered with medium large nodules.

In growing woolly-podded vetch it should be handled as common vetch, except that a little less seed may be used in seeding. Fifty pounds per acre is sufficient.

HORSE BEAN.

The horse bean (*Vicia faba*) has been but little grown in California. The broad bean, however, which differs from the horse bean only in having larger and broader seeds and pods, has been grown as a vegetable for a number of years in a few localities.

Experimental tests in California during the past few years indicate that the horse bean has considerable value as a green-manure crop, especially in the southern part of the State. (See fig. 9.)

The plant has an upright stem which is quite leafy, but little branched. The leaves, as well as the stems, are quite large, but comparatively soft and succulent until well matured. The root system consists of a strong taproot, with a fairly well-developed fibrous system radiating from this. The roots penetrate quite deeply into ordinary soils and aid in overcoming "plow sole." The taproot, as well as the smaller roots, when well inoculated has many large nodules, indicating that it is a good nitrogen gatherer. In southern California horse beans are usually well inoculated and have many large nodules. In northern California, thus far, they have had very few or no nodules the first year they have been grown. Consequently, when grown without artificial inoculation they amount to but little, although when inoculated they succeed quite well.

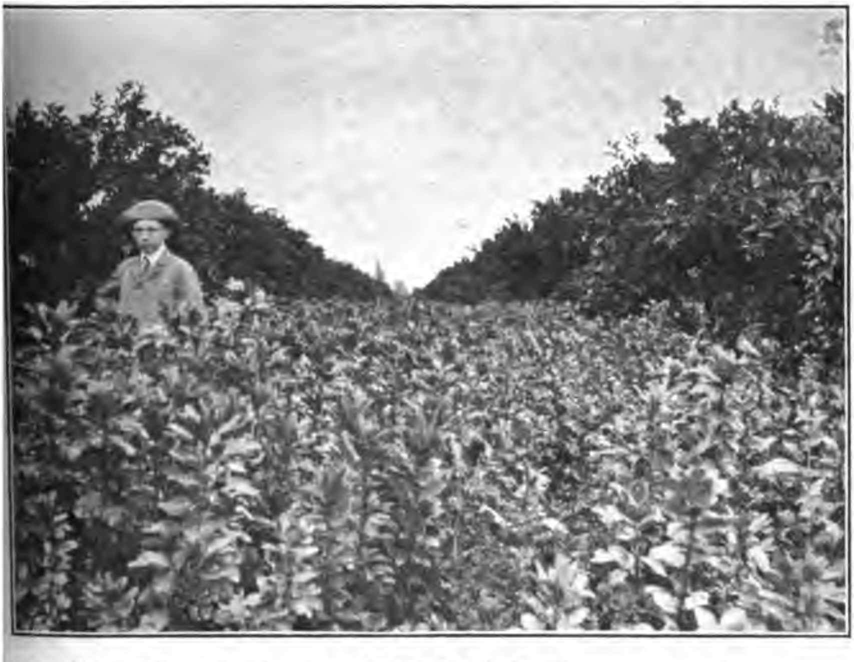

FIG. 9.—View in a citrus orchard in southern California, showing horse beans grown as a green-manure crop.

Although the stems of the horse bean are quite large they decompose readily when turned under for green manure. In comparison with other green-manure crops horse beans make a good growth, but in an orchard will not withstand trampling like the vetches. As the seeds are large a considerable quantity is required in seeding, unless the field is planted in drills more than the ordinary distance apart. As the individual plants make a comparatively large growth they will stand this method of planting, and if sown in drills 18 or 24 inches apart a good yield will be secured. The season for planting is the same as that of vetch.

TANGIER PEA.

The Tangier pea (*Lathyrus tingitanus*) was originally introduced into this country from northern Africa. It is an annual legume resembling in general the garden sweet pea, to which it is related.

During the past few years considerable attention has been given to the Tangier pea to determine its value as a green-manure crop, and results thus far indicate that it is of considerable value for this purpose. It makes a strong growth, yielding a heavier tonnage per acre than the common vetch (see Tables I, II, and III). Its dense growth enables it to overrun and smother out weeds, which is one of the very noticeable qualities of this crop. Though the stems are quite large they are not very succulent and stand considerable rough usage, being well adapted for orchard use in this respect. The large growth made by Tangier peas makes them somewhat difficult to turn under with an ordinary moldboard plow; with a disk plow but little trouble in this respect will be experienced.

The root system is well developed. It has a more nearly definite central root than vetch, and the roots penetrate the soil more deeply. The nodules are large and numerous, indicating that the plant is a good nitrogen gatherer.

For a green-manure crop Tangier peas should be handled like common vetch, except that the seeding should be heavier, from 70 to 75 pounds of seed per acre being required for obtaining the best results.

COST OF SEED OF GREEN-MANURE CROPS.

The cost of seed of green-manure crops is a factor of considerable importance in determining their relative value. The high price of seed may be the cause of the elimination from use of an otherwise good crop. In most orchard sections it is hardly practicable for the orchardist to attempt to raise his own seed, though with crops having good seeding habits this could be readily done. The commercial seed grower will very likely be depended upon for the supply of seed needed. The price that growers will pay for any new crop will probably be largely determined by the price of seed of common vetch and of field peas. A slightly higher price for a superior crop would undoubtedly be paid. However, a superior crop and cheap seed are what is desired.

The practice of allowing enough seed to ripen in the orchard to volunteer a crop from year to year is the cheapest method of seeding a green-manure crop, but this is practicable only in deciduous orchards without irrigation, where the returns will justify but very little expense in connection with such a crop. Under such conditions bur clover in particular can be effectively used.

TABLE IV.—*Seed production per acre of various legumes at Chico, Cal., 1909. Plats one-twentieth acre.*

Name.	Rate of seeding.	Yield of seed.
	Pounds.	*Pounds.*
Tangier pea	72	210
Tangier pea	77	630
Fenugreek	28	490
Fenugreek	21	490
Black bitter vetch	48	600
Black bitter vetch	45	1,800
Black bitter vetch	76	1,980
Black-purple vetch	58	300
Black-purple vetch	36	380
Black-purple vetch	36	580
Black-purple vetch	48	400
Woolly-podded vetch	45	290

In Table IV is presented the seed yield of various new green-manure crops discussed in this bulletin. These yields were taken from $\frac{1}{20}$-acre plats that had been sown primarily for a green-manure crop test and not for seed production. So the yields in some instances are much lighter than would have been the case had the crop been sown for seed.

It is quite probable that at Chico, where these crops were grown, conditions are not so favorable for the seed production of such plants as the woolly-podded vetch and the black-purple vetch as are the conditions in western Oregon, where seed of common vetch and hairy vetch is grown commercially. This is probably also true of the Tangier pea, though not so much so of the black bitter vetch, which does well at Chico. The yields presented in the table and the general character of the crops indicate that seed should be produced as cheaply as that of common and of hairy vetch, and in the case of black bitter vetch somewhat more cheaply. The seeding habits of black bitter vetch are such that an orchardist could easily raise his own seed if necessary, and where it is desirable to grow some crop in a young orchard he might raise the seed with profit.

Of the crops mentioned, the production of seed will cost most with the Tangier pea and the woolly-podded vetch, and least with the black bitter vetch. The cost of seed of common vetch and field peas varies from year to year. Seed of common vetch during the past few years has varied from 3½ to 5 cents per pound. When seeding at the rate of 60 pounds to the acre this would make the cost of seed from $2.10 to $3 per acre.

Seed of field peas has been about the same price per pound as that of common vetch, but as 80 pounds of seed per acre are needed in seeding, this makes the cost from $2.80 to $4 per acre.

Bur clover seed is advertised at from 25 to 30 cents per pound, hulled. When seeding at the rate of 20 pounds of seed per acre this makes the cost of seed from $5 to $6 per acre.

The wholesale price of fenugreek seed in the European market is from 2½ to 3 cents per pound. The price to the grower would of course be somewhat in advance of this, but should not exceed 5 or 6 cents. When 30 pounds of seed per acre are used, this would make the cost of seeding from $1.50 to $1.80 per acre.

Black bitter vetch seed, though not handled in quantity by American seedsmen, can be secured in foreign markets and imported at a cost that should make the price to the grower about the same or less than that of common vetch. When seeding at the rate of 70 pounds of seed per acre, this would make the cost of seeding from $2.40 to $3.50 per acre. As stated elsewhere, the fact that black bitter vetch yields a heavy crop of seed in California and has exceptionally good seeding habits should make it possible to place California-grown seed on the market at a much less cost than that of common vetch.

SUMMARY.

California soils, though often very fertile, are generally deficient in humus.

Within recent years green-manure crops in California have been given special attention.

The only places where green manures are being used extensively are the citrus and walnut orchards of the southern part of the State.

Deciduous orchard sections of the State are using practically no green-manure crop.

By the use of green manures a generally improved condition of orchards has been secured, as shown by a more healthy appearance of the trees and more and better fruit.

The early seeding of green-manure crops is desirable for obtaining the best results.

Green manures should be turned under before the trees start new growth in the spring.

Heavier seeding than is ordinarily practiced is advised.

Common vetch and field peas are the most generally used green-manure crops, the vetch being the most popular.

Peas or common vetch sown in the fall without irrigation will not, except in the most favorable years, make sufficient growth to be turned under early as a green manure, but when thus sown will make a good growth later in the spring.

Field peas, common vetch, and bur clover are adapted to quite varied conditions, and are being grown in a limited way throughout the State.

In any part of the State having a mild winter a green-manure crop of peas or common vetch will succeed if sown early in the fall with irrigation.

Bur clover seems to be of most value for deciduous orchard conditions, while the woolly-podded vetch promises to be of value for the same conditions.

Fenugreek and bur clover are used to a limited extent, fenugreek being especially adapted to the region near the coast.

Hairy vetch is not well adapted for use as a green-manure crop in California.

Black bitter vetch, black-purple vetch, woolly-podded vetch, horse beans, and the Tangier pea are promising new green-manure crops in comparison with common vetch.

Green-manure crops need no inoculation in California, horse beans in the northern portion being the only known exception.

The growing of a summer green-manure crop in California orchards is not advisable.

Local as well as sectional conditions in the various parts of the State vary considerably, and must be taken into consideration in determining the best crop for green manure as well as the best method of handling the same.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 191.

B. T. GALLOWAY, *Chief of Bureau.*

THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

THE PHILADELPHIA
OCT 26 1910
MUSEUMS.

BY

G. N. COLLINS,

BOTANIST, CROP ACCLIMATIZATION AND ADAPTATION INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 5, 1910.

Sir: I have the honor to transmit herewith a paper entitled "The Value of First-Generation Hybrids in Corn," by Mr. G. N. Collins, a Botanist of this Bureau, and recommend its publication as Bulletin No. 191 of the Bureau series.

This report shows how the vigor and fertility of hybrids may be utilized to increase the yield of the corn crop, in addition to other factors of adaptation and breeding.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

INTRODUCTION.

The use of first-generation hybrids offers one of the most promising methods of increasing the yield of corn. The evidence that crossing can in general be relied upon to give an immediate increase of vigor and productiveness appears conclusive, yet the practice seems never to have been applied on a commercial scale. The plan of utilizing first-generation hybrids involves the making of the cross anew each year, and this is readily feasible with corn. Many efforts have been made to develop hybrid varieties, but the increased vigor and productiveness that result from hybridization appear to be confined largely to the first generation and to disappear gradually in later generations.

The present paper reports experiments with a series of first-generation hybrids between widely different types of corn and brings together the results of previous experiments. Investigations that warrant the placing of confidence in this method of increasing the yields of corn are scattered over a long period of years, and most of them appear to have been made in ignorance of similar work previously reported. Individual experiments taken alone have not made it perfectly clear that the results were not accidental, but the assembled evidence forces the conclusion that the increases secured in the first generation by crossing varieties can be made a factor of production comparable in importance to breeding.

It was indicated more than three decades ago that seed produced by crossing two varieties of corn could be relied upon to produce larger crops than the parents, and that this increase was to a great extent lost in following generations.

At about the time when it was discovered that an increase in yield and vigor followed the crossing of two varieties, the attention of investigators was attracted to the possibility of the improvement of corn through what then appeared the more scientific methods of selection. The latter idea was in accord with the most advanced ideas of evolution, while the former appeared as an isolated fact discovered by accident.

It was natural that investigators should follow out what appeared to be the more logical and scientific method. The fact that yields could be materially increased by simply crossing two varieties was lost sight of. Great strides have been made in the knowledge and possibilities of corn improvement by selection, but until the past few years the possibility of utilizing the vigor of first-generation hybrids of corn has remained almost exactly where it was left by the pioneer experimenters.

PECULIAR HABITS OF THE CORN PLANT.

Even after the increased vigor of first-generation hybrids became recognized as a general principle it was not appreciated that the peculiar habits of the corn plant made its commercial application to this crop entirely feasible. Corn is peculiar among the important crop plants in being wind-pollinated and in having the male and female flowers on widely separated parts of the plant. This combination of characters permits the production of crossed seed in large quantities by the simple expedient of planting two varieties together and removing the tassels from the plants of one variety, which will then produce only hybrid seed. The importance of this fundamental difference between the flowering habits of corn and those of other crops has not been sufficiently appreciated. Systems of breeding developed for other plants have been applied to corn, diverting attention from this more simple method of improvement made possible by the peculiar habits of the plant. The use of first-generation hybrids will doubtless be found applicable to other crops, but in few will its utilization be so easily accomplished as with corn.

FIRST-GENERATION HYBRIDS CONFUSED WITH HYBRID VARIETIES.

The utilization of crossing as a means of securing increased yields was further retarded by the failure to realize that the high performance of the generation immediately following a cross is not maintained in subsequent generations. Much effort has been expended in attempting to establish hybrid varieties, overlooking the possibilities of the direct use of hybrid seed of the first generation. The fact that few of the hybrid varieties have been found to have permanent value should not prevent the appreciation of the vigor that immediately follows the crossing.

Until recently hybrids were usually made by hand-pollination and the quantity of first-generation seed was necessarily small. That the plants from this seed were especially vigorous and productive aroused the hope that a happy combination of varieties had been discovered, and attention was at once centered on the increase of the ock and its further improvement. In the succeeding generatic iversity appeared and before the desired uniformity could ag e secured through selection the increased vigor resulting from t rossing had disappeared.

VIGOR OF HYBRIDS A FACTOR OF PRODUCTION.

Comparatively few recent experiments with a direct bearing he value of first-generation hybrids have been reported, but hat have been made confirm the earlier results. Taken in conne ion with the experiments to be reported in the present paper th stablish beyond question that the vigor of first-generation co ybrids is a means of securing increased production that is capab f a very wide application. As soon as the general public becom cquainted with such a simple and inexpensive means of increasi he yield of this most important crop, a rapid extension of t ractice should follow. The great need is for detailed informatic egarding the particular varietal combinations best adapted to t ifferent local conditions. At present the data are so meager th xperiments must proceed empirically, but the lack of detaile information should not obscure the importance of the subject n stand in the way of utilizing the results already accomplished.

While it would appear safe to recommend this method to all cor producers, the object of the present bulletin is rather to urge th inauguration of experiments in as many parts of the country a possible. It is much as though the possibilities of increased yield through the application of commercial fertilizers were still unappreciated by the general public and experiments to prove their efficac were being conducted in a few isolated localities. Indeed, th utilization of first-generation hybrids appears to have more genera application than the use of commercial fertilizers, but the need fo experiments under a wide range of conditions is equally great. A in the use of fertilizers, conditions may perhaps be found where th increase from crossing will be slight or none at all, but even thi result should not detract from the fact that under most condition the increases are significant.

POPULAR BELIEF IN THE SUPERIORITY OF FIRST-GENERATION HYBRIDS.

Though the possibility of utilizing the vigor of first-generation hybrids is only beginning to be appreciated from the scientific standpoint, the increased yields that result from crossing have probably been utilized unconsciously since prehistoric times. It is a regular custom among many native American tribes to carefully plant seeds of different varieties in each hill of corn. This is done for the purpose of increasing the yield. Though the expected increase is usually associated in the minds of the natives with superstitious ideas regarding sexuality in the plants, the vigor secured by such crosses may well have been an important factor in establishing this custom with primitive tribes.

The value of first-generation hybrids is further recognized in a widespread belief among practical seed growers that the plants produced by accidental crosses of pure strains are often exceptionally vigorous. The following statement from Dr. W. W. Tracy, who has had a wide experience in the practical breeding of plants and in commercial seed production, voices this belief:

> The second step is the selection of a few plants which shall come as near to the ideal as possible and the saving of the seed of each of these separately. I recommend this instead of selecting the *best one* because it often happens that the very best plant is in reality a crossed one which owes its superiority to a cross of some exceptionally vigorous but otherwise inferior plant, and this "bar sinister" will be revealed in the inferior quality of plants grown from its seed.[a]

PREVIOUS EXPERIMENTS WITH FIRST-GENERATION HYBRIDS.

EXPERIMENTS IN MICHIGAN.

That the immediate result of crossing two varieties is to increase the yield was shown by definite experiments as early as 1878 by Dr. W. J. Beal, of the Michigan Agricultural Experiment Station. The plan for such experiments had been outlined two years before, in 1876, the same year that Darwin published his classical work on self and cross fertilization in plants, but without knowledge of Darwin's results. Doctor Beal's first statement was as follows:

> To improve or infuse new vigor into varieties (or races I should more properly call them) I propose in case of corn and some other seeds to get seeds from remote parts where it has been grown for some years, and plant near each other and mix them.[b]

Even at this early date Doctor Beal appreciated the fact that the benefits were largely confined to the first generation.

> The good results of such crossing will last for several years, though most apparent the first year.[c]

The nature of the first experiment and its relation to the similar experiments of Darwin are shown in the following quotation:

> From several different sources in remote parts of our State I obtained white dent corn and yellow dent corn for seed. So far as possible I obtained good seed from men who had raised the corn for ten or more years in succession on the same farm.

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[a] Tracy, W. W. Importance of Uniformity of Varietal Character in Vegetable Seeds. Market Growers' Journal, October 30, 1909, p. 2.

[b] Beal, W. J. Report, Michigan Board of Agriculture, 1876, p. 206.

[c] Loc. cit.

After a lapse of more than thirty years it is hardly possible to improve or refine the method of experimentation as outlined by this pioneer. His method of comparing yields by alternate-row plantings was also more perfect than that of his successors and is again coming into use as the best that has yet been devised.

In 1881 Doctor Beal made another cross, between two varieties from Oakland and Allegan counties, respectively, and reported the results of the cross as follows:

> The Oakland County seed corn was the better of the two. Owing to an accident we failed to raise any pure Allegan County seed in 1881. The "crossed corn" was only compared with pure Oakland County seed raised last year at the college.
>
> In the spring of 1882, on good soil in a portion of the vegetable garden, three rows of "crossed seed" were planted in rows alternating with three other rows of pure Oakland County seed of 1881. By an oversight each row of each lot was not kept separate. The pure seed yielded 57½ pounds in the ear; the "crossed seed" yielded 69¼ pounds in the ear. In other words, the crossed stock exceeded the pure stock as 121 exceeds 100, nearly.[a]

EXPERIMENTS IN INDIANA.

Of the five cooperators entering into the agreement with Doctor Beal to test first-generation hybrids, Prof. C. L. Ingersoll, of Purdue University, seems to have been the only one who reported results. In this case it appears that seed of the variety detasseled was not saved, so that the hybrid was compared with only the male parent. Since in this case the cross was made between two strains of the same variety, this failure does not entirely vitiate the results. The experiment is reported as follows:

> I took corn from Delaware County and also from Switzerland County, in this State, and planted as in first year's directions.
>
> The tassels were removed from the Delaware County corn, so that it was certainly fertilized by pollen from the Switzerland County corn. Both were a white dent variety. The result of corn raised was as follows:
>
> Delaware County (hybrids), 122 pounds, 27.89 bushels per acre.
>
> Switzerland County, 63 pounds, 14.40 bushels per acre.
>
> Switzerland County (alone), 72 pounds, 16.46 bushels per acre.
>
> These results, although small, seem to show that in this instance at least, and with the experiment half completed, there is a marked difference in cross-fertilized and self-fertilized corn when the seed from the crossing is obtained from widely separated localities and is of the same variety.[b]

It seems that the experiment was again attempted two years later[c] and hybrid seed was secured, but subsequent reports of the university do not show that the experiment was ever completed, Professor Ingersoll having left the institution.

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[a] Beal, W. J. Report, Michigan Board of Agriculture, 1881-2, p. 136.

[b] Seventh Annual Report of Purdue University for 1881, p. 87.

[c] Ninth Annual Report of Purdue University for 1883, p. 72.

PREVIOUS EXPERIMENTS WITH FIRST-GENERATION HYBRIDS.

EXPERIMENTS IN MAINE.

The only reference by subsequent workers to Doctor Beal's exp nents so far as we have ascertained is that of Prof. J. W. Sanborn eporting a similar experiment in Maine.

> Professor Beal found that outcrossed corn, as the average of two years of trial, g s 131 is to 100 for inbred corn. I found the same result, or as 252 is to 179, or fodder as 490 is to 350. The facts have a deep significance to our farmers.[a]

EXPERIMENTS IN ILLINOIS.

Nine years after the work of Doctor Beal and apparently in ign ance of his results, Mr. G. W. McCluer reported the results of a ser of crosses made at the Illinois Agricultural Experiment Station. did not give actual yields, but noted the average size of the ear compared with that of the parents in 18 crosses comprising 14 diff ent combinations of dent, pop, soft, and sweet corn. In 16 of the crosses, or 12 of the 14 different combinations (2 were duplicates a 2 reciprocals), the ears of the first-generation hybrid were larger th an average of the parents, and in 4 of the crosses the hybrid ea were larger than those of either parent. One of the exceptions stated to have been planted in an unfavorable location. The decrea in the other case was 4.6 per cent. The average increase in weig for the whole series was 14 per cent.

With respect to the uniformity of the first-generation hybrid McCluer says:

> During the first growing season the uniformity of the crossed plats was very notic able. Of 142 plats planted with sweet corn, pop corn, and these crosses it is safe say there was as much uniformity in any one of the crossed plats as in any, and ve much more than was found in most, of the plats planted with pure varieties.[b]

The following year, 1891, a number of the ears from this crossbre corn were again planted and Mr. McCluer says:

> Nearly all the corn grown a second year from the crosses is smaller than that grow the first year, though most of it is yet larger than the average size of the parent vari ties. The cause of this apparent decrease in size, as compared with the previo year, can only be guessed at. It can not be attributed to the season, because th Queen's Golden–Common Pearl pop corn and Gold Coin–Flour corn crosses grow in 1891 show as large a proportionate increase in size of ear as is shown in an of the crosses grown in 1890. There is probably a strong natural tendency in th crosses to revert to the size as well as the form of the parent types. This is shown i the Leaming sweet-corn crosses, in which the corn reverting to the dent is large than that reverting to the sweet types. Or the loss of size may be due to a diminu tion in some way of the vigor imparted by crossing.[c]

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[a] Sanborn, J. W. Indian Corn. Agriculture of Maine, Thirty-Third Annual Re port, Maine Board of Agriculture, 1889–90, p. 78.

[b] McCluer, G. W. Corn Crossing. Bulletin 21, Illinois Agricultural Experimen Station, 1892, p. 85.

[c] Op. cit., p. 96.

In view of the interest that attaches to these early experiments, Mr. McCluer's tabulated results are given as follows:

TABLE I.—*Results of Mr. G. W. McCluer's experiments with corn hybrids at the Illinois Agricultural Experiment Station, showing the effect on the size of ear.*

Cross.	Weight of 10 ears of the male variety.	Weight of 10 ears of the female variety.	Average weight of 10 ears of the two parent varieties.	Weight of 10 ears grown from cross the first year.	Weight of 10 ears the second year after the cross, ounces.
White dent—Queen's Golden	81	34.5	57.75	76	Ears like the dent type............ 64 Ears like the pop corn type........ 52.5
Queen's Golden—White dent	34.5	81	57.75	64	Ears like flint corn................. 55 Ears like pop corn type............ 47.5
Black Mexican—Queen's Golden	36	34.5	35.25	47.5	Types not separated............... 43.5
Queen's Golden—Common Pearl pop corn.	34.5	27.5	31	42	Not grown a second year.
Leaming—Mammoth	87.5	61.5	74.5	91	Corn grown from yellow dent kernels 96 Corn from white dent kernels....... 90 Corn from sweet kernels............ 74
Leaming—Mammoth	87.5	61.5	74.5	82	Not grown a second year.
Leaming—Mammoth	87.5	61.5	74.5	80.5	Not grown a second year.
Leaming—Triumph	87.5	46.5	67	83	Corn from dent kernels............ 86 Corn from sweet kernels........... 68
Leaming—Eight-rowed	87.5	41	64.25	72	Corn from white dent kernels...... 80 Corn from yellow dent kernels..... 75 Corn from sweet kernels........... 58
Gold Coin—Flour corn	63	39	51	78	Has not yet been grown a second year.
Black Mexican—White dent	36	81	58.5	51	From flint kernels of flinty ears.... 53 From flint kernels of sweet ears..... 40 From sweet kernels of flint ears.... 39 From sweet kernels of sweet ears... 38.25
Stowell's—Eight-rowed	57.5	41	49.25	47	From selected ears................. 49 From self-fertilized ears........... 38 From cross-fertilized ears.......... 43
Stowell's—Triumph	57.5	46.5	52	52.5	From self-fertilized seed........... 31 From cross-fertilized ear........... 48.5 Do........................... 41 Seed from selected ears............ 54 Seed from self-fertilized ears........ 39
Stowell's—Mammoth	57.5	61.5	59.5	61	Self-fertilized ear, plat 88.......... 43 Self-fertilized ear, plat 76.......... 52 From cross-fertilized ear, plat 86.... 55 From cross-fertilized ear, plat 87.... 45.5 Seed from selected ears............ 55
Stowell's—Gold Coin	57.5	62.5	60	62.5	From self-fertilized ear, plat 89..... 48 From self-fertilized ear, plat 90..... 54 From self-fertilized ear, plat 91..... 54 Seed from selected ears............ 58 Seed from self-fertilized ear......... 48
Gold Coin—Triumph	62.5	46.5	54.5	58.5	From cross-fertilized ear, plat 93.... 56 From cross-fertilized ear, plat 92.... 50 Seed from selected ears............ 49
Gold Coin—Eight-rowed	62.5	41	51.75	56	Seed from selected ears............ 50
Gold Coin—Eight-rowed	62.5	41	51.75	58	Not grown a second year.

In the bulletin mentioned the practical possibilities of this method of increasing yields were indicated, as follows:

> The fact that increased yields can be obtained by crossing two varieties is pretty certainly established, and a few farmers are changing their practice accordingly. This is quite easily done by planting in one row one variety and in the next another variety, and removing the tassels of the one as soon as they appear. The ears forming on the rows having the tassels removed will be fertilized with pollen from the other rows, thus producing a direct cross between the two varieties. The seed should be selected from the rows having the tassels removed, and the experiments indicate that it will pretty certainly give a larger yield than the average of the parent varieties when planted under like conditions.[a]

The above quotation indicates that the authors considered the principle as established and worthy of practical application. No explanation has been offered why the matter was again allowed to rest at this point, but so far as can be learned no one has since practiced the growing of first-generation hybrids on a commercial scale.

In 1893 four additional crosses were planted, three of the four giving increases over the average of the parents, the average increase being 9.5 bushels, or 7.7 per cent. The results are shown in Table III.[b]

TABLE III.—*Results of experiments by Morrow and Gardner with corn hybrids at the Illinois Agricultural Experiment Station in 1893.*

Variety.	Yield per acre.	
	Number of ears.	Air-dry corn.
		Bushels.
Champion White Pearl	7,680	37.3
Burr's White	10,200	38.6
Average	8,940	38
Champion White Pearl—Burr's White Cross	7,080	28.4
Leaming (average 4 plats)	8,07C	34.6
Burr's White	10,200	38.6
Average	9.135	36.6
Leaming—Burr's White Cross	9,480	41.7
Edmonds	7,740	28.3
Murdock (average 4 plats)	9.600	35.7
Average	8.670	32
Edmonds—Murdock Cross	9,840	41.4
Edmonds	7,740	28.3
Burr's White	10,200	38.6
Average	8.970	33.5
Edmonds—Burr's White Cross	9,360	37.8

The fluctuations in the yields of the different varieties and crosses in this experiment are so wide that little confidence can be placed in sults. The omission of single members from the series wo aterially change the average. The lack of uniformity in the co ons is indicated by the great disparity between the yields of duplic arieties in this experiment, which ranged as high as 15 bushels cre.[a]

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[a] Morrow, G. E., and Gardner, F. D., loc. cit.

[b] Morrow, G. E., and Gardner, F. D. Experiments with Corn. Bulletin 31, Illinois Agricultural Experiment Station, pp. 359–360.

EXPERIMENTS IN NEW YORK.

After a further lapse of fifteen years, the subject was ag pproached from a somewhat different direction by Dr. G. H. Sh f the Carnegie Biological Laboratory at Cold Spring Harbor, N. n his first paper he suggests the possible use of first-generati ybrids in the following statement:

> The problem of getting the seed corn that shall produce the record crop, or wh all have any specific desirable characteristic combined with the greatest vigor, n ossibly find a solution, at least in certain cases, similar to that reached by Mr. Q impson in the breeding of hogs by the combination of two strains which are onl e highest quality in the first generation, thus making it necessary to go back e ear to the original combination, instead of selecting from among the hybrid offspr e stock for continued breeding.[b]

The following year Doctor Shull stated his views in greater det nd reported on the result of crossing two closely related strain Before these results can be properly appreciated it will be necessa o briefly consider the problem from Shull's standpoint. It is co idered that even the most nearly uniform varieties of corn consist umerous strains, "elementary species" or "biotypes," all more ess mixed and hybridized. To this miscellaneous hybridizi Doctor Shull attributes the vigor and fertility of a variety. Th method he suggests for the improvement of corn is to isolate th different strains and by making predetermined combinations t ascertain which will be the most favorable for agricultural purpose It is fully recognized that isolating the pure strains or biotypes wi very greatly reduce their vigor and yield, but by making a combina tion of the proper strains it is believed that the degree of fertility o the cross will reach that of the most productive plants in the origin mixed strain and that an increase of the total yield can be obtaine in this way.

Two self-fertilized strains which were separated from a commo stock in 1904 and continuously self-fertilized since that time wer reciprocally crossed in 1907. In 1908 the yields of these reciproca crosses were compared with each other, with the self-fertilized parents and with crossbred stocks of the original variety. Reduced to bushels per acre and placed in tabular form, the yields reported by Shull were as follows:

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[a] Morrow, G. E., and Gardner, F. D., op. cit., p. 338.

[b] Shull, G. H. The Composition of a Field of Corn. Report, American Breeders Association, vol. 4, 1908, p. 300.

[c] Shull, G. H. A Pure Line Method in Corn Breeding. Report, American Breeders Association, vol. 5, 1909, p. 51.

Strain A, self-fertilized	23.5 bushels.
Strain B, self-fertilized	25.0 bushels (estimated).
A×B	74.4 bushels.
B×A	78.6 bushels.
General average of crossbred stock	75.0 bushels.

From Doctor Shull's standpoint the important point in the above comparison is the increase of 1.5 bushels per acre which the average of the crossed pure strains shows over the average of the cross-pollinated original stock, an increase of 2 per cent.

At the same time a comparison was also made between the yield of self and cross pollinated ears of the same isolated strain. The yield from the cross-pollinated seed was 30 per cent greater than that from the self-pollinated ear. As an instance of the increased vigor of the first-generation hybrid this example is of interest, since it indicates that an increase in yield follows the crossing of even the most closely related plants.

To many producers of corn it will appear hardly practicable to apply this system on a commercial scale. Neither does it appear reasonable on theoretical grounds to look on these anomalous self-fertilized strains as representing the natural condition. It would seem that even the most advantageous combinations might be found without reducing the varieties to the verge of extinction before the cross is made.

But no method of investigation should be rejected for purely theoretical reasons. Until other experimental data are available the effect of previous breeding upon the vigor of the hybrids must remain an open question. The importance of the subject demands that all the phases shall be considered, and those who hold to the conception of "biotypes" and "pure germ cells" will do well to experiment along the lines suggested by Doctor Shull.

EXPERIMENTS IN CONNECTICUT.

A more extensive series of crosses was made by Dr. E. M. East at the Connecticut Agricultural Experiment Station. His results are stated as follows:

> The F_1 generation of 30 maize crosses were grown in 1908 on well fertilized land in Connecticut. They were planted 3 feet 6 inches each way, about four stalks to the hill. Seeds from the same parent ears[a] which were used to make the crosses were also grown for comparison. Only 50 hills of each of the crosses and of each parent could be grown on account of limited space, but the soil conditions were such that a

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[a] "The parent ears were, therefore, one year older, but their germination was good, and their growth equal to inbred seed of the same ages as the hybrid seed."

two inbred strains which without crossing were among those which gave the lowest yields of any represented in the experiment.

Regarding other crosses, Doctor East states:

> In the remainder of the field every possible combination of dent, flint, and sweet maize was grown, and in every case an increase in vigor over the parents was shown by the crosses. It is to be regretted that comparable yields could not be obtained in every instance, but, as a matter of fact, the differences were so apparent to the eye that it is almost unnecessary. The figures presented do not show the average increase to be expected by a cross. The manuring was heavy, the cultivation intensive, and the yields were beyond the ordinary. But they do show that in practically every case a combination of two high-bred varieties of seed corn is more vigorous than either parent.[a]

A NEW SERIES OF HYBRIDS BETWEEN DIVERSE TYPES.

The crosses thus far considered have in all cases been between strains that are comparatively closely related. The most violent crosses are among those reported by McCluer where varieties of sweet and dent, pop and dent, and sweet and pop corns were included. The diversity between these types may seem considerable, representing as they do the extremes of the types now cultivated in the United States, but looked at botanically these varieties appear closely related when compared with the very diverse types that exist in the Tropics.

Over the whole of the United States the interchange of seed has been so extensive and the culture is so nearly continuous that all characters are to a great extent shared by the whole series of varieties, even the most divergent types being distinguished by characters that differ in degree rather than in kind. Even before the advent of the white man the nomadic tendencies of the North American Indians must have operated against any complete isolation of types.

The sedentary habits of the Indians of tropical America are in strong contrast with those of the more northern tribes, and together with the great diversity of natural conditions have operated to produce an enormous number of very distinct types, showing numerous specialized adaptations to different conditions, the agricultural significance of which is only beginning to be appreciated.

As an instance of one of these divergent groups there may be mentioned a type of corn cultivated in parts of the lower plateau of Mexico in a region that receives such scanty rainfall that similar regions in this country would be thought entirely unsuited for corn growing. This corn is so different from the types with which we are familiar that it was given specific rank by Bonafous and named *Zea hirta*.[b] The leaf sheaths are densely covered with long hairs borne on tubercles, the leaves are few and very long and slen the tassel is frequently unbranched, the spikelets are in group four or more instead of two, and the clusters are opposite each o instead of alternate. Even the root system is distinct from tha any of the common varieties of the United States, being spread near the surface of the ground where the only available water i be secured in the regions where this type is native. Many vari inside this type differ among themselves much as the classes of f dent, and pop corns differ from each other. In fact, a closely sin series exists in this tropical type, there being varieties which juc by the ears, would be classed as flint and others as pop and dent co

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[a] Op. cit., pp. 179–180.

[b] Bonafous, M. Annales des Sciences Naturelles, vol. 17, 1829, p. 156.

While this type is one of the most distinct, many other tro forms possess characters and habits that are entirely absent or faintly indicated in United States varieties. Peculiarities of o tropical types will be mentioned in connection with the diffe crosses that are about to be described.

With a view to securing types adapted to sections of the cou where United States varieties are unsuccessful, a considerable s of tropical types and varieties has been brought together. In season of 1908 about 75 crosses were made among these trop varieties, and also between them and several United States varie A number of these hybrids were grown in the summer of 190 Lanham, Md., a few miles from Washington, D. C. The pa varieties of 16 of these crosses were included in the plat and t behavior noted in comparison with the crosses. The experim was considered as merely preliminary and but 16 hills of e variety were grown. While this number is altogether too small t conclusive as a comparison of the values of the different cros the results as a whole are very significant as an illustration of general value of first-generation hybrids. It becomes evident t the increase in vigor that earlier experiments have proved to be rule with crosses of more or less closely related strains has also a v wide application among even the most primitive, unselected, diverse types of corn. In 14 of the 16 crosses the yield excee the average of the parents. In 12 cases it exceeded the yield of eit parent, the average increase for the whole series being about 53 cent.

In the following brief account of the hybrids and their pare the descriptions will for the most part be confined to the usu recorded characters of height, yield, and character of the ear, wh data are sufficient to make the results of this experiment compara with those previously reported. Detailed observations of the beha of the parental characters in these and other hybrid combinati have been made, but are not needed for the purpose of this rep

Abnormalities will be briefly noted as a possible indication of the violence of the cross.

HYBRID AH 3, MARYLAND DENT BY HOPI.

Female parent.—An unselected white dent grown in Maryland. The particular plant used as the female parent was grown from the seed of a red ear. This proved to be the most prolific of the uncrossed strains; perhaps on account of its being the only locally grown variety in the experiment. No abnormalities were discovered in any part of the plant or in the ears. Average height, 6 feet 10 inches. The 16 plants grown produced 21 ears and 2 nubbins, weighing 19 pounds.

Male parent.—A variety grown by the Hopi Indians of Arizona. The most striking characteristics of the type are the very large male spikelets and enormous ear stalks. The color of the particular ear used in making the cross was a slaty blue. No abnormalities appeared in the plants grown in this experiment, though in Kansas this strain produced a number of ears with inverted grains, the embryo on the lower side, toward the base of the ear, and also a number of grains with double germs. Average height, 8 feet 10 inches. The 27 plants grown produced 21 ears and 2 nubbins, weighing 20 pounds.

Hybrid.—In spite of the fact that both of the parents yield pollen very abundantly, 6 of the 16 hybrid plants failed to produce pollen. No other abnormalities were observed. The plants were rather diverse, some resembling one parent and some the other. The ears, however, were as uniform as those of either parent and partook of the characters of both. Average height, 7 feet. The 16 plants grown produced 21 ears and 2 nubbins, weighing 20.1 pounds.[a]

HYBRID AH 4, TUSCARORA BY CINQUANTINO.

Female parent.—An 8-rowed soft variety, grown by the Tuscarora Indians of New York. The variety is early and suckers profusely, many of the suckers terminating in ears. Average height, 5 feet 8 inches. The 16 plants grown produced 14 ears and 10 nubbins, weighing 8.5 pounds.

Male parent.—A variety imported from Hungary under the name Pignoletto. A very small seeded, many-rowed type that would be classed as a pop, though unlike any of the American varieties of pop corn. This class of corn is known to the trade as "Cinquantino." The variety is small, without suckers, and very early. No abnornalities. Average height, 4 feet 4 inches. The 14 plants gro produced 14 ears and 1 nubbin, weighing 3.3 pounds.

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[a] The yields of the hybrids and the parent varieties, reduced to pounds per plant, are brought together for comparison in Table IV, p. 29.

Hybrid.—Plants and ears intermediate. No abnormalit Average height, 6 feet 7 inches. The 15 plants grown produced ears and 14 nubbins, weighing 11.3 pounds.

HYBRID DH 1, KANSAS DENT BY CHINESE.

Female parent.—A white dent developed by Mr. Elam Bartho mew, of Stockton, Kans. The variety has never been closely br but has been grown continuously for a number of years and kept by selection of ears. No abnormalities. Average height, 7 feet inches. The 29 plants grown produced 26 ears and 4 nubbi weighing 28.6 pounds.

Male parent.—A variety of corn from China, with waxy en sperm, leaf blades borne on one side of the stalk, and silks p duced in the angle of the leaf blades.[a]

The parent plant was grown from white seed separated from t imported mixture and had the erect monostichous leaf blades th characterize this variety. The second-year plants from Americ grown seed showed these characteristics in a much less mark degree than those grown from imported seed. No abnormaliti Average height, 4 feet 7 inches. The 32 plants grown produced ears and 9 nubbins, weighing 12.4 pounds.

Hybrid.—In the early stages the plants resembled the Chin parent in having erect monostichous leaf blades, but this charac was less marked later in the season. The plants remained dark gre during a very dry season. The only indication of abnormality w the frequent production of pistillate flowers on the terminal infl escences of the suckers. The ears were intermediate in size a appearance and as uniform as those of either parent. Average heig 6 feet 9 inches. The 16 plants grown produced 27 ears and 7 nu bins, weighing 17.5 pounds.

HYBRID DH 2, CHINESE BY CHIHUAHUA.

Female parent.—The same as the male parent of hybrid Dh1.

Male parent.—A starch variety from Chihuahua, Mexico. Th variety is peculiar in having the longest leaf sheath at the top of t plant and in having the leaf sheaths covered with fine velvety hai No abnormalities. Average height, 8 feet 9 inches. The 14 plan grown produced 13 ears and 2 nubbins, weighing 9.7 pounds.

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[a] This variety is more fully described in Bulletin 161 of the Bureau of Plant Ind try, U. S. Dept. of Agriculture, 1909, entitled "A New Type of Indian Corn fr China."

Hybrid.—The plants of this cross exhibited greater diversity than was shown in any other cross. Two of the plants were so exactly like the female parent, both in plant and ear characters, as to arouse the suspicion that the precautions against foreign pollination had been imperfect and that the particular grains producing these plants were self-pollinated. This appears the more probable from the nature of the Chinese plants, which makes it especially difficult to exclude pollen from the tips of the silks that appear directly in the angles of the leaf blades. While the plants showed the complete range of the parental characters, the ears, with the exception of those noted above, were fairly uniform. One interrupted ear was produced; that is, a portion of the ear near the middle produced only staminate instead of pistillate flowers. Average height, 8 feet 3 inches. The 16 plants grown produced 25 ears and 18 nubbins, weighing 15.25 pounds.

HYBRID DH 3, HOPI BY CHINESE.

Female parent.—A plant from a white seed of the Hopi variety described as the male parent of hybrid Ah3.

Male parent.—White Chinese. The same as the male parent of hybrid Dh1.

Hybrid.—Plants fairly uniform, showing characters of both parents. Ears remarkably uniform, more nearly resembling the female parent. The only abnormal feature was the frequent exsertion of the ear beyond the husks. Average height, 8 feet 4 inches. The 16 plants grown produced 28 ears and 2 nubbins, weighing 20.4 pounds.

HYBRID DH 4, CHINESE BY XUPHA.

Female parent.—Plant from a white seed of Chinese similar to the male parent of hybrid Dh1.

Male parent.—A black, semistarch variety from Salvador. No abnormalities. Average height, 8 feet 8 inches. The 14 plants grown produced 21 ears and 5 nubbins, weighing 8.8 pounds.

Hybrid.—The hybrid ear from which these plants were grown was poorly matured. Plants and ears exhibited a number of abnormalities. Eight suckers and two main stalks bore small ears at the base of the tassel, below which were a number of supernumerary leaves. In two cases the margins of the leaf sheaths were grown together, forming a cylinder. About half of the ears produced staminate flowers; some were interrupted and many had a long staminal portion at the tip. Average height, 7 feet 10 inches. The 16 plants grown produced 18 ears and 18 nubbins, weighing 8.6 pounds.

Male parent.—A very tall variety from the high mountains of the western part of Guatemala. The ears are borne very near the top of the plants and are consequently late in maturing. Although apparently an unproductive type the yield here given is little indication of what the variety might do if the season permitted maturing. The cross was made to test the possibility of making crosses between varieties that represented the extremes in size. Average height, 9 feet 6 inches. The 15 plants grown produced 9 nubbins, weighing 1.5 pounds.

Hybrid.—Plants intermediate but exhibiting considerable irregularity in size. Ears averaging 7 inches long, fairly uniform. The principal abnormality was shown in the leaves, which were crumpled and distorted in all the plants. The color was so dark as to be abnormal. While this cross showed distinctly an increase in vigor over that of the parents, the yield of both parents was so small that the amount of the increase should not be considered. Average height, 6 feet 7 inches. The 15 plants grown produced 16 ears and 6 nubbins, weighing 6.25 pounds.[a]

HYBRID KH 31, BROWNSVILLE BY GUATEMALA RED.

Female parent.—The same as the female parent of hybrid Dh6.

Male parent.—A red flinty-seeded variety with 12 to 16 rowed ears, from the lowlands of Guatemala. No abnormalities. Average height, 8 feet 11 inches. The 14 plants grown produced 6 ears and 12 nubbins, weighing 4.31 pounds.

Hybrid.—Ears fairly uniform. Plants and ears without abnormalities. Average height, 10 feet 2 inches. The 32 plants grown produced 29 ears and 10 nubbins, weighing 15.6 pounds.

HYBRID KH 62, GUATEMALA RED BY SALVADOR BLACK.

Female parent.—The same as the male parent of hybrid Kh31.

Male parent.—A black variety from Salvador not unlike the female parent. Two plants of this variety produced branched ears. The ear stalks also curved up instead of down, so that the ears crossed the main stem. The 15 plants grown produced 3 ears and 12 nubbins, weighing 4.1 pounds.

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[a] East states "I have repeatedly tried to cross Giant Missouri Cob Pipe maize (14 feet high) and Tom Thumb pop maize (2 feet high), but have always failed. They both cross readily with varieties intermediate in size, but are sterile between themselves." (See East, E. M., A Mendelian Interpretation of Variation that is Apparently Continuous, The American Naturalist, vol. 44, 1910, p. 82.

It may also be noted that this small variety was successfully crossed with a large Mexican dent whose average height was 11 feet 7 inches. In these experiments the Giant Missouri Cob Pipe corn averaged only 8 feet 4 inches.

HYBRID MH 16, ARRIBEÑO BY HAIRY MEXICAN.

Female parent.—Similar to the female parent of Mh15, but a larger variety. Average height, 9 feet. The 15 plants grown produced 10 ears and 7 nubbins, weighing 5.8 pounds.

Male parent.—Same as the male parent of hybrid Mh15.

Hybrid.—Plants similar to hybrid Mh15, but more robust and uniform. A striking characteristic of this cross was that the leaf blades, though slightly shorter, were much broader than those of either parent. The fifth blade of the hybrid averaged 31.3 by 5.6 inches. The corresponding blade of the female parent averaged 35.4 by 4.1 and the male 31.5 by 4.7 inches. Average height, 9 feet. The 14 plants grown produced 9 ears and 7 nubbins, weighing 6.6 pounds.

HYBRID MH 17, HAIRY MEXICAN BY CHINESE.

Female parent.—The same as the male parent of hybrid Mh15.

Male parent.—The same as the male parent of hybrid Dh1.

Hybrid.—Plants and ears fairly uniform. One difference between the parent strains is that in the female parent when more than one ear is produced at a node the secondary ear is borne directly in the axil of the prophyllum. The male parent resembles the United States varieties in having the first secondary ear borne in the axil of the first husk. Of the hybrid plants that produce secondary ears one-half resembled the male and one-half the female in this respect. The only abnormalities noted were a tendency in a number of plants to have the leaves on the upper part of the plant crowded and one ear with a staminate spike at the tip. Average height, 7 feet 4 inches. The 16 plants grown produced 18 ears and 4 nubbins, weighing 9.8 pounds.

HYBRID MH 25, MEXICAN DENT BY TOM THUMB.

Female parent.—A large Mexican variety with a pronounced tendency to produce large secondary ears. One interrupted ear was produced. Average height, 11 feet 7 inches. The 15 plants grown produced 10 ears and 15 nubbins, weighing 7.8 pounds.

Male parent.—The same as the female parent of hybrid Gh2.

Hybrid.—Plants resembling the female parent in most particulars. About one-half the ears exceeded the husks. Average height, 6 feet 7 inches. The 16 plants grown produced 22 ears and 13 nubbins, weighing 8.6 pounds. Though this cross would seem to have been quite as violent as Gh2, no pronounced abnormalities were found.

YIELDS OF FIRST-GENERATION HYBRIDS.

The following table shows the behavior of the 16 crosses and their parents. The yields are given as yield per plant and were calculated

Experiments by the writer with primitive types crossed with one another and with United States varieties, first reported in the present paper, gave increased yields in 14 out of 16 cases, the average increase being 53 per cent.

Though the average of the yields of the parent varieties may be considered as a fair standard for judging the increased yields of the hybrids from the standpoint of heredity, the practical value of hybrids must be determined by comparing their yields with those of the more productive parents. To secure evidence on this point it will be necessary to consider the crosses which have been made between good-yielding varieties grown under favorable conditions, excluding those in which there is great disparity in the yields of the parents.

The following table includes all the crosses here reported in which the parents appear to have been fair-yielding standard varieties giving approximately the same yields.

TABLE V.—*Increased yield of hybrid corn over the more productive parent.*

	Percentage of increase of hybrid over better parent.
Beal (p. 11). "Varieties essentially alike"	52
Beal (p. 11). "Varieties essentially alike"	10
Beal (p. 12). Hybrid compared only with better parent	21
Ingersoll (p. 12). Strains of the same variety	35
Morrow and Gardner (p. 15). Parents differed by 2.6 bushels per acre	0
Morrow and Gardner (p. 15). Parents differed by 15.0 bushels per acre	—8
Morrow and Gardner (p. 15). Parents differed by 8.5 bushels per acre	17
Morrow and Gardner (p. 15). Parents differed by 13.0 bushels per acre	4
Morrow and Gardner (p. 15). Parents differed by 5.8 bushels per acre	15

It will be seen from Table V that in six of the nine crosses significant increases were obtained over the yield of either parent, and two of the three exceptions should, perhaps, have been excluded, since the differences between the yields of the parents were 15 and 13 bushels, respectively.

The experiments thus far reported are too few to warrant any conclusions regarding the nature of the crosses which may be relied upon to yield the greatest increase. It is naturally to be expected that the percentage of increase will be greatest between low-yielding strains, but the greatest increase in bushels per acre may follow the crossing of the more highly developed strains.

Probably none of the crosses here considered were between carefully bred and locally adjusted strains. What the results of such crosses will be is yet to be determined. Since the most carefully selected strains are more or less inbred, a substantial increase would be expected from crossing two such unrelated inbred strains unless they have already approached the limit of production of the corn plant.

That the utilization of first-generation hybrids will be found of special value in the drier parts of the country was clearly indicated by the behavior of the hybrids described in these pages.

The season during which these hybrids were grown was one of exceptional drought, affording an excellent opportunity for observing the drought-resisting ability of the different strains and their hybrids. The rainfall at Washington, D. C., for April, May, and June was slightly below the average, and for July and August it was 4.07 inches, less than one-half the normal.

The series included varieties from localities with such extremes of climate as obtain in the plateau region of Mexico and the moist Tropics of the lowlands of Central America. While the differences between the varieties in their ability to withstand drought were obvious, the most striking differences of this kind were between the hybrids and the pure strains. Almost without regard to the nature of the parents the hybrids remained dark green and vigorous when nearly all of the pure strains were giving evidence of the lack of moisture by their curled leaves and yellow color. This ability to withstand drought may have been a factor in the increased yields which the hybrids produced.

Experiments are being made with a series of hybrids in western Kansas and the dry Southwest with the idea of learning which crosses will prove best suited to these extreme conditions.

Experiments at the Virginia Agricultural Experiment Station indicate that first-generation hybrids may be found to withstand excessive moisture as well as drought. While the crosses were apparently undertaken with the idea of establishing hybrid varieties, the results so far as reported apply only to the first generation.

> The native varieties that were crossed with the western corns have developed three or four good strains, and out of some 350 samples tested here this year none have stood the wet season and made as good yields as the improved strains obtained by crossing pure-bred western corn with our best native varieties.[a]

Associated with the general increase in vigor in first-generation hybrids a certain measure of disease resistance may naturally be expected. Many plant diseases that are unable to attack vigorous plants are able to do serious damage to weaker varieties or to plants that are weakened by adverse conditions. The ability of the hybrids to resist drought might at the same time protect them against disease.

In the case of the corn smut, which was the only disease that affected any of the experiments, this factor of disease resistance does not appear to apply, for the attacks of the smut do not seem to

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[a] Vanatter, Phares O. Annual Report, Virginia Agricultural Experiment Station, 1906, p. 55.

Careful seedsmen who wish to extend the range of territory to which they can supply seed that will be equal or superior to the best locally selected seed should be willing to give careful consideration to the possibility of establishing regular supplies of first-generation hybrid seed for their customers.

FIRST-GENERATION HYBRIDS IN SWEET CORN.

While the production of sweet corn is influenced by very different considerations from the production of field corn, the evidence at hand indicates that the advantages of first-generation hybrids apply to sweet corn with even greater force than to field corn.

In sweet corn, as with field corn, the yield is an important item, and the experimental data here presented warrant the statement that the yield can be very materially increased by means of first-generation hybrids.

With sweet corn, however, the yield is not the only consideration; quality and uniformity are important factors that must be taken into consideration. As regards quality, the evidence indicates that in most cases it will be intermediate between that of the parents. If parents of good quality are chosen, the quality of the hybrid will be satisfactory. The proof of this rests not alone on the few cases where the quality of the first generation of crosses of sweet-corn varieties has been recorded, but on the general fact that the morphological characters of the first generation of crosses in corn are almost always intermediate between those of the parents. With respect to uniformity it may be said that experiments in crossing sweet varieties have not been recorded in such a way as to give direct evidence. On the other hand, experiments in the crossing of field corns make it certain that in this class, with properly chosen varieties, a perfectly satisfactory degree of uniformity can be secured. The first generation of a cross is usually quite as uniform as the parent strains, a condition naturally to be expected in view of the general tendency for all morphological characters to appear intermediate in the first generation. While the strict uniformity required in score-card ratings may not be assured, it is altogether probable that the uniformity of size, color, shape, and time of maturing required by the market will be fully met if reasonably uniform strains are selected as parents.

The important differences between sweet and field corn in the commercial methods of producing and handling seed are all of a nature to make the application of this principle more effective with sweet corn than with field corn. A much larger percentage of sweet-corn than of field-corn growers buy their seed, a practice that is much to be regretted where pure strains are used, since the lack of

From the standpoint of the investigation the failures of such experiments are often of even greater interest than the successes, since they may lead to better understandings of the factors involved.

In reporting results it would seem desirable to state the facts bearing upon as many of the following points as possible:

(1) *Names and descriptions of varieties crossed.*—While the names of commercial varieties are almost hopelessly confused, some designations are necessary for purposes of reference, and if these are accompanied by careful descriptions many errors may be avoided, as well as a needless duplication of work.

(2) *History of the varieties.*—This should be traced as far back as possible to throw light on the degree of relationship that exists between the varieties crossed.

(3) *Sources of seed and previous methods of breeding.*—Important differences may be expected even where the same varieties are used, depending on whether the seed has been self-pollinated or cross-pollinated; also whether it was the result of mass selection in the field or crib or was derived from a single ear.

(4) *Size of the hybridizing plat and the plats or rows in which the yields are tested.*—The ratio between the area devoted to each variety in the breeding plat and that in which the yield test of the same variety is made should be recorded, since it is a measure of the opportunity for selection. If the breeding or hybridizing plat is small in proportion to the area to be planted, it will be necessary to save a large part of the seed for planting and the opportunity for selection will be correspondingly small. The failure to take this fact into consideration is one of the reasons why large field plantings of pure-bred varieties so frequently fail to meet expectations of high yields indicated in the breeding plats, where a more rigid selection was practiced.

(5) *Extent of self-pollination in the parent varieties.*—Many varieties produce pollen so little in advance of the silks that a considerable proportion of the seed is self-pollinated, and this operates to diminish the yield of the resulting plants. In such cases a part of the increase that might be ascribed to the crossing of two varieties would in reality be due to the depressed yields of the parent varieties with which the cross is compared. To determine the increase actually due to the crossing, seed from detasseled plants of the parent varieties should be included in the yield test, together with ordinary wind-pollinated seed of the same varieties.

(6) *The method by which the yields are compared and the precautions against experimental error.*—In this connection it should be borne in mind that large plats do not insure greater accuracy. The larger the plat the greater the difficulty of obtaining equal conditions

One difficulty, however, with this reciprocal use of male and female parents would arise unless the varieties agree in length of season. No difficulty would be experienced in securing perfect pollination in a short-season variety used as the female parent, but if such a variety were expected to serve as the male parent the tendency to the early shedding of the pollen might leave little or none available for fertilizing a later variety used as a female parent.

The following directions, which have been sent out to several cooperative experimenters, give a concrete example of one of the ways in which the value of first-generation hybrids may be determined:

> Experiments as outlined below involve the use of two varieties and two separate plats. Varieties may be designated as No. 1 and No. 2, the plats as A and B. The plats should be sufficiently separated to prevent cross-pollination between them.
>
> It should be kept in mind that the increased yield can be expected only for the one year immediately following that in which the cross is made.
>
> Plat A is planted with alternate rows of No. 1 and No. 2. The rows planted with No. 2 are to have all plants detasseled. The crop of No. 1 and No. 2 is to be saved separately.
>
> Plat B is planted entirely with variety No. 2 and has alternate rows detasseled. The crop from the tasseled and detasseled rows is to be saved separately.
>
> At harvesting there will be the following lots of seed:
>
> (1) Plat A. Variety No. 1, field-pollinated.
> (2) Plat A. Hybrid between No. 1 and No. 2.
> (3) Plat B. Variety No. 2, field-pollinated.
> (4) Plat B. Variety No. 2, cross-pollinated.
>
> The yields in the year the cross is made should show the comparative value of the two varieties and the effect, if any, of detasseling on the immediate yield.
>
> A comparison of the yield from these four lots of seed the following year should show the yield of the first-generation hybrid as compared with the pure varieties and to what extent the increase, if any, is due to the elimination of self-pollinated seed.
>
> If plat B can not be provided, seed of variety No. 2 should be held for planting the following year in comparison with variety No. 1 and the hybrid seed.

If it is considered important to have the crop of a uniform color, yellow and white varieties should not be crossed, for the grains will be of different colors in the year following the cross. Crosses between dent and flint or between these and sweet corn would also result in a lack of uniformity with respect to the character of the seed. That such differences should occur while the other characters remain so nearly uniform may appear remarkable, but is explained by another of the peculiar habits of the corn plant. Unlike most other plants the seeds of corn show an immediate effect of pollen (xenia).[a] If a white-seeded variety is crossed by one with yellow or black seeds, the new seeds that are produced show the color of the male parent.

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[a] For a discussion of xenia, see Webber, H. J., Bulletin 22, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture, 1900.

yields than the average of the parents, the amount ranging as high as 95 per cent. The series includes experiments in six different States and embraces a wide range of varieties.

Similar increases are here reported in crosses between the members of a new series of types of corn from China, Africa, and the American Tropics, very different from United States varieties and very unlike among themselves. These experiments show that a very wide application of this principle is possible.

In addition to increased yields there is reason to believe that the increased vigor of first-generation hybrids may become an important factor of adaptation to different conditions of growth. The hybrids appear not to require the delicate adjustment to local conditions necessary to the proper performance of pure strains. The utilization of hybrids may be expected to extend the range of utility of the high-yielding types beyond the present range of adaptation of such varieties.

First-generation hybrids are a distinct factor in the problem of securing varieties of corn with adaptations that fit them for special conditions. The increased vigor which these hybrids possess should make possible their growth in regions where pure strains fail and should also provide some measure of disease resistance.

The advantage of crossing distinct varieties is equally applicable to the improvement of sweet corn and affords a measure of protection to those discovering new and valuable combinations.

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